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THE "CANALS" OF MARS.

W. W. PAYNE.

We have been much interested of late in the lively discussion that has been going on in scientific publications about the so-called "Canals" of Mars. We have given place to a considerable number of papers presenting the observations of many astronomers since the favorable opposition of Mars in 1877. These have included observations of Schiaparelli, W. H. Pickering, Percival Lowell, E. E. Barnard, Mr. Denning and those of many other astronomers of some experience in planet work.

The thing that is most prominent in the mass of writing that has appeared during the last twenty years is the very general agreement of the maps of the surface of Mars that have been made by so many careful and competent observers. This fact means much for the real advance of astronomy in a field beset with difficulties. Such observation can not be made with any but the best of telescopes. Such work can not be done, to any extent, where or when the atmosphere is unsteady, murky or dust-laden, and such details for map-making can not be proved by any power different from, or less than, the well trained human eye.

When an astronomer makes a study of these maps of the surface of Mars, he feels pretty sure of one thing, that he has a picture before him of what competent and faithful observers have really seen; for he knows that so many witnesses could not be mistaken in seeing the same details in almost endless variety, unless they had a real existence. The scrutiny of these details of the surface markings of the planet has been so sharp and so often repeated that the specialists in the study of Mars know if changes in them take place. They know what they ought to see at a given time and in a given phase of the planet, and if some of the minute details of the minor markings do not appear as they

should, at a predicted time, such facts are noted with especial care, as matter for further critical observation. In this way a great many observations of the detailed study of the planet have been accumulating in recent years, of which no one can speak particularly and safely who has not been patiently through this kind of work, and has come into that stage of its knowledge which is possessed only by the trained observer. Much less will he be able to dispute what an able observer shall say about the correctness of observations or the accuracy of maps constructed from such observations.

In reading the work of the great astronomers of the world one is impressed with the fact that those noted men seemed to get things, in some, measure, by a kind of astronomical intuition, just as a good reader of any language will get the meaning of a strange word by the connection and the sense it should bear in the place where it stands. In somewhat the same way we must give credit to trained observing for a kind of knowledge which others can not possibly possess by other means, or get from other sources.

In the second place when the astronomer comes to the point of making a map of the surface of the planet Mars, he will use his own observations, diligently compare them with the work of many other trustworthy observers and then commit his results, thus verified, to paper, as a map for reference bearing a given date. This is distinctly the work of observational astronomy in the line of the surface study of a planet by the aid of the visual telescope. In this, photography is of no use, nor will the spectroscope aid him in the least. He must here depend wholly on the principles of the old astronomy, so-called, for all the data which he is to work into the details of a surface map. It is the visual telescope, the micrometer and the trained eye that are the essentials in this fascinating field of investigation. The maps of the surface of the planet Mars made by Schiaparelli, Lowell, Pickering, Flammarion and many others are pieces of astronomical work that are now classical in astronomy, and they are likely long to remain so, because they were made by the very best means and methods now known to that science.

So far we can speak of the "canals" of Mars quite securely and satisfactorily; but when we go much further, and begin to draw inferences from observations and the maps that astronomers have made, we at once enter a field of conjecture and uncertainty. This is really the third stage of astronomical study, or that of any branch of science, through which the investigator must go

to determine a law of nature. It is the theoretical stage of knowledge; it is a condition precedent to law and fact and it is just as necessary, as any other in the logical train which leads to new truth and new knowledge in any direction.

The great trouble that is apt to arise in the discussion of new data in astronomy is the fact that the disputants too often lose their patience, and sometimes their good sense, in their treatment of the honest views of opponents. Truth always suffers in such dealing. But,

"Truth crushed to Earth will rise again," and those who suffer most are those who fail to be candid and perfectly just in the treatment of opposing opinions.

Let this discussion go on, fairly and fully, not foolishly, scornfully or needlessly prolix but honestly, thoroughly and to the finish, if there is data enough to carry it to so wide and so satisfying induction. But, we think it ought to be remembered always that all theories evolved from earnest and successful discussion, must stand the crucial tests of appropriate observation some time, before they can be accepted as anything more than working theories in the progress of establishing that which is new.

In the matter we are now speaking of, we have been much interested in what appears in the May number of *Knowledge*, 1904, page 87, in an article having the same title as we have chosen. Mr. Maunder, the writer of that article has treated the views of his opponents so fairly and so conscientiously that we wish to adopt it entirely, and have given it below in full with the illustrations.

"Several correspondents having expressed a strong wish that I should give some reply to Mr. Story's letter on this subject, I will endeavor to do so; not without reluctance, as the line which Mr. Story took seemed, in my opinion, hardly likely to advance our knowledge."

"If I may briefly summarize Mr. Story's objections to the paper communicated by Mr. Evans and myself to the Royal Astronomical Society last June, they come under three heads. He objects to me as the author, to the methods employed, and to the deductions drawn."

"The first objection is of course a somewhat delicate one for me to handle. It deals rather with the personal than with the scientific, and I have no inclination to fill the columns of Knowledge with detailed evidence of my claim to be considered an "expert" on the subject of Mars. Let it suffice that as long ago as 1877,

I had made a thorough study of the planet, using the fine 12¾-inch Merz refractor of Greenwich Observatory. In 1892 and 1894 I also used the 28-inch Grubb refractor—certainly one of the most perfect objectives in existence. I give two or three ex-

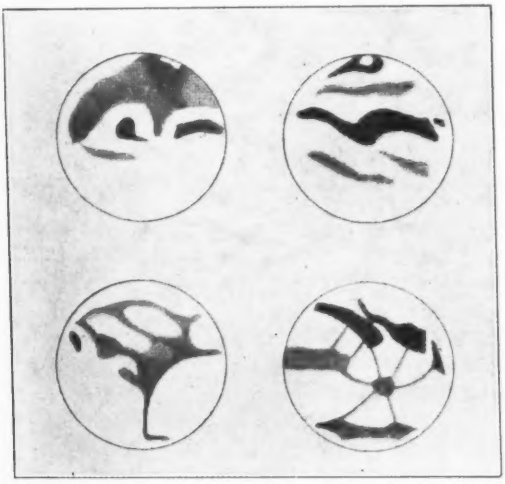


FIG. 1.—DRAWINGS OF MARS MADE THE 12¾-INCH REFRACTOR OF THE ROYAL OBSERVATORY, GREENWICH.

	h	m		h	m
1. 1877 Sepeember 29th	10	10	2. 1877 September 24th	11	43
3. 1879 November 5th	13	5	4. 1882 January 9th	12	2

amples of my earlier drawings, from which it will be seen that I had recorded some of the markings now familiar to us as "canals" and "oases," even before Schiaparelli had published his results, and quite a number before they had been generally recognized by observers."

"So much for the person, next for the methods. Mr. Lowell and Mr. Story both appear to object to the employment of terrestrial experiments to elucidate planetary appearances. Mr. Lowell's opinion to this effect may be found in his letter published in the "Observatory" for January, 1904, p. 49: "Permit me, in conclusion, to point out to you * * * that the only evidence germane to the matter is to be got from astronomical observations directed to that end." But as Mr. Story points out, Mr. Lowell himself has set on foot terrestrial experiments for the express purpose of drawing inferences with respect to his observations of Mars, and Mr. Story approves of his so doing. Eliminating what is common to the two cases, the one of which meets with

Mr. Story's approval, and the other with his disapproval, the only residuals are Mr. Lowell on the one hand and myself on the other, and the statement is reduced to the simple proposition that he approves of Mr. Lowell and disapproves of me, irrespective of our actions. In other words, his second objection is but a more diffuse way of restating his first."

"But to take the matter seriously, let us see precisely what is the point where Mr. Lowell's views and my own diverge. It is not in the chief markings of Mars. Mr. Lowell sees and draws these substantially as I saw and drew them in 1877, and as Beer and Mädler drew them in 1830. It is not in respect to the appearance of the "canals;" I observed and drew "canals" as far back as 1877, and though of course Mr. Lowell has seen and drawn far more "canals" than I have, those that I saw were substantially of the same character as his; and in the discussion of this question I have been most careful, both in writing and speaking, always to point out that I was not throwing doubt either on the fidelity or the skill of any of the observers of Mars. Mr. Evans and myself wrote: "It would not be in the least correct to say that the numerous observers who have drawn 'canals' on Mars during the last twenty-five years, have drawn what they did not see. On the contrary, they have drawn, and drawn truthfully, that which they saw." ("Monthly Notices, Vol. LXIII., p. 499). Nor have I ever asserted or assumed "that the canals are seen as very faint lines, so faint that their existence is doubtful even to experienced observers." I know the reverse by actual experience."

"We agree on a third point. Mr. Lowell is absolutely convinced, and in this I am quite at one with him, that it is not possible that an actual network so geometrical as that which he represents can be the result of purely physical causes. Mr. Story has no doubt seen the very fascinating book which Mr. Lowell published on "Mars" in November, 1895, and has read the pages 148-154."

"After this we differ. Mr. Lowell attributes this confessedly utterly unnatural network to the handiwork of intelligent beings who have woven over their planet these "grotesque polygons" to use Schiaparelli's expression."

"This, be it noted, is inference, not observation; and an inference which demands the assumption that, were Mars brought much nearer to us, or our power of seeing greatly improved, these grotesque polygons would still persist, and would never resolve themselves under better seeing into markings which we could

reasonably ascribe to the unaided processes of Nature."

"My inference is different; the unnaturalness may be due to the imperfection of our seeing. I rely on well-known facts respecting the theory of vision and the structure of the eye, and the eye is our necessary instrument for observation. We have no right to resort to the unknown and the artificial, before we have exhausted the known and natural methods of explaining a phenomenon. My inference is one based on the observed effects of known causes; Mr. Lowell's inference is an excursion into fairyland."

"We know that the smallest single dark marking on a bright ground which can be seen by an observer of perfect sight, without optical assistance, must have a diameter of at least 34 seconds of arc. This diameter depends upon the size of the rods and cones of the eye which receive the visual impression, and compose the sensitive screen. It is therefore an inevitable limit. As this diameter is necessary for the object to be merely perceived, or, in other words, to create any sensation at all, it follows that in order that the actual shape of the object may be recognized, its diameter must considerably exceed this limit, otherwise it will be seen as a truly circular dot, whatever its actual shape."

"This is the case for small isolated markings just within the limit of visibility. The case is different for extremely elongated markings; the increased length of a marking will compensate for diminished breadth up to a certain limit, but not beyond it. For a line of indefinite length the limit of breadth approaches two seconds of arc. A line of a breadth below one second of arc is invisible, no matter what its length; but it must have a breadth many times this amount before it can be seen as anything else than a mere line—before irregularities in shape and breadth can make themselves apparent."

"In naked-eye vision, therefore, there is a considerable range within which small objects, whatever their true shape or nature, can only be seen as dots or as lines. The result is that these two forms are certain to come in evidence whenever we are dealing with objects too minute to be fully and properly defined."

"The problem becomes more complicated when we are using optical assistance, as there is a limit of definition belonging to the telescope as well as to the eye. But the principle remains the same; the result of adding the limitation of the telescope to the limitation of the eye being that the actual magnification of the telescope can never be nearly as effective as it is nominally. A power of 300 on the best telescope in existence, and under the

best atmospheric conditions, would never show the features of the Moon as distinctly as they would be seen if the Moon were brought 300 times as near."

"Mr. Story and Mr. Lowell both object that terrestrial (or, as they are more usually called, "laboratory") experiments are altogether beside the mark when applied to the interpretation of astronomical observations. The contention is a ridiculous one, and if logically applied would render it impossible to determine the instrumental errors of a transit circle by the use of meridian marks, collimators, or mercury trough, or the personal equation of an observer, except by actual stellar observation. They would also forbid us to identity the lines of solar or stellar spectra by comparison with those of any terrestrial element."

"But since it is contended that Mars alone can give us valid information on the subject, to Mars let us refer. If we turn to the drawings made by Beer and Mädler in 1830, two small objects exceedingly like one another appear repeatedly. These are two dark circular spots, the one isolated, the other at the end of a gently curved line. Both recall the "oases" which figure so largely in many of Mr. Lowell's drawings, and the curved line at the termination of which one of the spots appears, is not un-

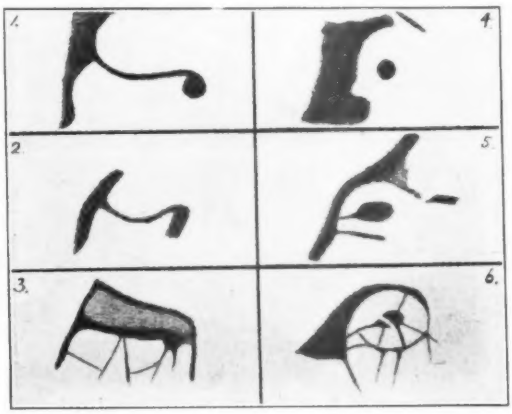


FIG. 2.—SINUS SABÆUS AND LACUS SOLIS.

1.	Sinus Sabæus. . . .	Beer and Madler	1830.
2.	" "	Lockyer . .	1862.
3.	" "	Schiaparelli. .	1890.
4.	Lacus Solis	Beer and Madler	1830.
5.	" "	Lockyer . .	1862.
6.	" "	Schiaparelli. .	1890.

like the representation which has been given of several of the "canals." There can be no doubt that in the year 1830 no bet-

ter drawings of Mars had appeared than those to which I have referred, and that in representing these two spots as truly circular Beer and Mädler portrayed the planet as they best saw it. The one marking we call today the *Lacus Solis*, the other the *Sinus Sabæus*, and we can trace the gradual growth of our knowledge of both markings from 1830 up to the present time. The accompanying sketches of the same region by Lockyer, in 1862, and by Schiaparelli, in 1890, illustrate well how the character of the markings revealed themselves with increased telescopic power and experience in the observer.

"At first it seemed a little speck
And then it seemed a mist,
It moved and moved and took at last
A certain shape I wist.
A speck, a mist, a shape."

If Beer and Mädler, in 1830, had argued that the precise circularity of these two spots, as they appeared to them, was proof that they were artificial in origin, would they have been correct? Would not the answer have been valid that a spot too small to be defined must appear circular, and that, therefore, the apparent circularity probably covered detail of an altogether different form? We know that it would. Yet it is that same argument in a far stronger form against which Mr. Lowell and Mr. Story are contending today. Beer and Mädler only drew two of these spots; Lowell shows over sixty. Beer and Mädler's two spots seemed to them precisely alike; how utterly different those two spots appear to us today the diagram may serve imperfectly to indicate. Mr. Lowell's sixty or more "oases," with one or two exceptions, appear all of the same character. Will any one dream that if the next seventy years brings telescopic development equal to that shown in the last seventy, the present uniformity of Lowell's "oases" will persist, any more than the likeness of the two spots observed by Beer and Mädler? We need not even wait for the seventy years. Up to the present moment I have carefully avoided anything like criticism of the drawings of any observer of Mars. I have repeatedly stated that I accepted them as being both faithful and skillful representations of what the observers saw. But it is necessary here to point out that the extreme simplicity of type of both "canals" and "oases," as shown by Mr. Lowell, is not confirmed by the best observers. In the last number of "Knowledge" Mr. Denning writes (p. 67): "There are really many distinctions in the canal-like markings; some of them are quite broad and diffused shadings, while others are narrow,

delicate lines." The Rev. T. E. Phillips has recently insisted strongly ("Monthly Notices," Vol. LXIV., p. 40) on the same fact, and I could increase the testimony indefinitely. There can be no doubt that the best observers not merely agree in stating that the "canals" differ very widely in their characteristics, but they also agree closely in the characteristics they assign to special "canals." With regard to Lowell's observations I can, of course, speak only with reference to those which he has published, but speaking with reference to these there can be no doubt that he fails to exhibit that wide variation in character between certain "canals" upon which these and other leading observers are fully agreed. This seems to me clear proof (so far as his published drawings go) not of superior conditions and skill on Mr. Lowell's part, but of a most marked inferiority in one respect or the other. Whether it be the location of his observatory that is at fault, or the definition of his telescope, or his own personal skill in observation, or most probable of all, in delineation, the fact remains that—despite the multiplicity of his observations and the perseverance, which cannot be too highly praised and too fully recognized, with which he has observed Mars in season and out of season—he has failed to record differences apparent to a consensus of other first-rate observers. Especially he has failed to recognize what Denning and Schiaparelli had recognized as early as 1884, that many of the "canals" were very far from being straight lines of uniform breadth and darkness, but showed evident gradations in tone, and irregularities occasioning breaks and condensations here and there. Of all the thousands of drawings of Mars which I have examined, those that most perfectly corresponded to Mr. Lowell's were the work of a young novice and were made in by no means an ideal station, using a small home-made telescope."

"It is made an argument in favor of the actuality of the "canals" that they have been seen with such distinctness, or with such frequency. The argument is based upon a very complete ignorance of the appearance of the fictitious "canals" observed in the experiments made by Mr. Evans and myself. I have myself been completely taken in by a little drawing on which the Syrtis Major and Sinus Sabæus were shown. As I looked at it by far the most insistent feature was a straight, narrow, intensely black line corresponding to the Phison. Yet that astonishingly vivid impression was really due to the integration of two or three feeble lines, irregular, broken, and serpentine curves, and half a dozen utterly invisible dots. If I had looked at that

drawing a thousand times, or if a thousand other observers had examined it under the same conditions as to distance, they could only have seen what I saw—a dark, straight line, as sharp as if cut by a graving tool."

"The change in the distinctness of the "canals," consequent on the progress of the Martian seasons, was no discovery of Lowell's; the fact was realized by Schiaparelli very early in his observations. But so far from rendering it more probable that the "canals" indicate artificial water-ways, it affords a most serious argument against their having that character. For water cannot flow uphill, yet the water from the melting polar snow, according to Lowell, must flow upwards to reach the equator. If, with Lowell, we consider the dark markings on Mars to be vegetation rather than water, they would change in appearance with the seasons whether they were of natural origin and irregular shape, or were artificial and symmetrical; and Mr. Lowell's 8500 observations do not increase the probability of his theory more than 85 or 8½ would do. A "canal" or an "oasis," if seen only as a straight line or a circular dot, that is to say, if seen only in the simplest possible form, affords no proof that the precise form under which it appears has any actuality. It is only when the object begins to show detail that we are sure that we are beginning to see it as it is. And one of the most convincing testimonies that Mr. Evans and myself have been following the right line has been shown by the attitude which the most experienced observers of Mars have adopted towards our inquiry. They have claimed, as Mr. Denning did in last month's "Knowledge," that certain "canals" are undoubtedly real, for they have been resolved or partially resolved into minuter details, being "composed of small, irregular condensations." Others they have admitted may be "canals" only in appearance, being actually either "the edges of half-tone districts or the summation of very minute details." In both the claim and the admission they are in perfect accord with the position held by Mr. Evans and myself. On the other hand, Antoniadi, Barnard, Denning, Molesworth, Stanley Williams, have all held themselves aloof from the bizarre delineations and yet more bizarre theories which Lowell has promulgated. Most striking of all, Mr. W. H. Pickering, who preceded Mr. Lowell in his argument that the water supply in Mars is restricted, and in the recognition of the system of "oases," who further has had the opportunity of observing with Mr. Lowell's telescope and in the climate of Arizona, has not only frankly accepted our position, but has supported it by direct

photographic proof. Mars, unfortunately, does not lend itself to photography, but the Moon does; and Mr. Pickering has found confirmation of our experiments as to the building up of straight-line systems from imperfectly seen details by comparing his drawings of certain lunar formations with actual photographs."

JESUIT ASTRONOMY.

WM. F. RIGGE, S. J.

PART II. CONCLUDED.

Observations.

The observations made by Jesuits during the 19th century are practically all the product of their four greater observatories of Rome, Stonyhurst, Kalocsa and Georgetown, in which alone some extended technical work has been possible, since all the rest either are of too recent a date or were built only for purposes of education. Even at these four observatories the work has been intermittent, principally on account of the pressure of other duties and the want of means, since they all are (or were) private observatories entirely dependent upon the charity of individual benefactors.

The Sun.

It is well within the bounds of moderation to assert that no work of any merit has been written on the Sun during the last thirty years without bringing in the name of Father Secchi. Born June 29, 1818, Fr. Angelo Secchi entered the Society of Jesus November 3, 1833. In 1849 he took charge of the Roman College Observatory, and rapidly became one of the foremost astronomers of his time. His work on the Sun is well summed up in his book Le Soleil, which will ever remain a classic in astronomical literature. He was one of the first to use the spectroscope upon the heavenly bodies, and he was by its means able to formulate a theory concerning the nature of sun-spots, prominences, faculæ, the corona and the whole Sun which has received the highest commendation and is quoted extensively in the writings of the best authors. To recount in detail Fr. Secchi's work on the Sun would be practically to give the whole theory as presented in our astronomical text books, a proceeding which would be as lengthy as it is unnecessary.

Fr. Perry, of Stonyhurst College, England, was another great student of the Sun. Born August 26, 1833 in London, he be-

came a Jesuit November 14, 1853. He had charge of the observatory from 1860 to 1862 and again from 1868 until his death in 1889. Besides the eminent work he did in meteorology and magnetism, such as the magnetic surveys of France in 1868 and 1869 and of Belgium in 1871, the routine work he inaugurated in Stonyhurst included the daily drawing of the Sun when possible, the measurement of the depth of the chromosphere, the observation of the heights, positions and directions of the prominences, and the recording of the spectra of sun-spots,—a long program that he most faithfully and consistently adhered to during the last ten years of his life. "With regard to faculæ, Fr. Perry established the fact that they do not precede the birth of a spot, but are most numerous and wide-spread when it disappears. Again, he has stated with regard to the distribution of faculæ, that it is much more general than that of the spots, many being visible even near the Sun's poles. Nor would it appear that the view that faculæ lag behind a sun-spot receives any confirmation from the Stonyhurst drawings."* The "veiled spots," independently discovered at Stonyhurst, have been watched with persistent patience for several years. The mean depth of the chromosphere was found to be about 4000 miles.

But Fr. Perry probably came most prominently before the notice of the scientific world on account of his many important astronomical expeditions, "in fact, it has been stated by those who ought to know best, that he was a member of more scientific expeditions than any living astronomer.† On December 22, 1870, he observed a total eclipse of the Sun at Cadiz in Spain. Filmy clouds prevented the complete success of his work. In 1874 he was appointed by the astronomer royal to command the expedition to Kerguelen or Desolation Island in the South Indian Ocean in order to observe the transit of Venus on December 8 of that year. As the longitude of the place was to be determined with the utmost care, the program included 100 double observations of lunar altitudes or azimuths and 30 transits over the meridian, and it took a weary exile of five months to execute it. In 1882 Fr. Perry was again selected to lead another expedition to observe the second transit of Venus of the century, that of December 6, at Nos Vey, Madagascar. August 29, 1886, he observed a total solar eclipse at Carriacou in the West Indies. For the eclipse of August 19, 1887, he went to Russia, but the expe-

* The Scientific Work of Father Perry, by Fr. A. Cortie, in The Month, for April 1890.

† Ibidem.

dition was a complete failure on account of the clouds. On December 22, 1889, he observed a total eclipse at Salut, near Cayenne, in the West Indies, where he died of a pestilential fever five days later. Fr. Perry's photographs of the solar corona and spectroscopic work during the eclipses did much to advance the cause of science.

Fr. Fényi of the Haynald Observatory, Kalocsa, Hungary, has very faithfully carried on the program of solar work he proposed to himself in 1885, and the numerous and periodical publications of his observatory testify to his ability and his perseverance. He has observed the solar prominences with special care, and has systematically mapped them upon the Sun's limb. The more remarkable protuberances he has observed in detail, and as far as possible, noted the changes they undergo. Some of the results of his long series of observations have a bearing on the recent investigations of the interrelations of magnetic disturbances on the Earth and solar phenomena. He states* that he finds that the eruptions of the greatest prominences, except when they are metallic ones near large spots, never coincide with magnetic disturbances. Faculæ and spots have not the close relation to protuberances that is generally taken for granted. And those faculæ which appear outside of the active spot zone, are only sometimes and quite accidentally accompanied by prominences. The structure of the prominences, before they are torn to shreds, is almost always one consisting of stripes, bands or threads.

In a short summary† of his solar work he says that the greatest heights attained by the protuberances during the different years coincide remarkably with the period of sun-spot activity, the maximum of only 165″ in January 1887 falling very close to the minimum, and the enormous maximum of 690″ in September 1893 close to the maximum of the spot period. The heliographic latitude of these maximum prominences seems to follow no law, except that it never exceeds 41°.

The Planets.

In regard to the planets we again find everywhere the name of Fr. Secchi. Thus he was one of the first to see the so-called canals on Mars,‡ to observe Jupiter's third satellite as spotted,¶ etc. I also pass over Fr. Perry's observations of occultations

* Publications of the Haynald Observatory, No. 8, 1902.

† V. J. S. 33, pp. 315-318.

‡ Clerke's Hist. of Astron. p. 327.

¶ Idem, p. 339.

and of Jupiter's satellites.* The most prominent work on the planets was probably Fr. De Vico's determination of the rotation period of Venus and the inclination of its axis, which was considered so exhaustive that it was not questioned for half a century; and even today the controversy between De Vico's 24-hour and Schiaparelli's 225-day periods cannot be said to be closed.† Fr. De Vico also measured the eccentric position of Saturn in his rings and observed the motions of Mimas and Enceladus, the two inner moons, which had not been seen except by Herschel. Arago‡ praises him for the invention of an instrumental device that enabled these satellites to be seen in telescopes much smaller than the one used by Herschel.

The Stars.

In regard to work on the stars, we may again point to the indefatigable Father Secchi. Clerke says:¶ "The effective founders of stellar spectroscopy * * * were Father Secchi, the eminent Jesuit astronomer of the Collegio Romano, where he died, February 26, 1878, and Dr. Huggins, with whom the late Professor W. A. Miller was associated. The work of each was happily directed so as to supplement that of the other. With less perfect appliances, the Roman astronomer sought to render his extensive rather than precise; at Upper Tulse Hill, searching accuracy over a narrower range was aimed at and attained. To Father Secchi is due the merit of having executed the first spectroscopic survey of the heavens. Above 4000 stars were in all passed in review by him, and classified according to the varying qualities of their light. His provisional establishment (1863-67) of four types of stellar spectra has proved a genuine aid to knowledge through the facilities afforded by it for the arrangement and comparison of rapidly accumulating facts. Moreover, it is scarcely doubtful that these spectral distinctions correspond to differences in physical condition of a marked kind."

Fr. Secchi also made innumerable observations of double stars, as works upon that subject will show.

Father Hagen, of the Georgetown College Observatory, though not a founder of a branch of astronomy as was Fr. Secchi, has

* Monthly Notices R. A. S. vols. 33, 34, 38-49.

† POPULAR ASTRONOMY, No. 75, p. 290, and No. 109, p 518. Astronomische Nachrichten Nos. 3641, 3891, 3892.

‡ Bibliotheque de la Comp. de Jésus, vol. 8, p. 645, which refers to Comptes Rendues of Oct. 10, 1842, pp. 747, 750, 751.

¶ History of Astronomy during the Nineteenth Century, second edition, New York, 1897.

rendered such great service to the branch of variable star observation as to put it on a new footing. His Atlas Stellarum Variabilium has filled a long-felt want and has supplied observers with essential and reliable data with which to carry on their observations. The Atlas, which began to appear in 1899, consists of about 250 charts divided into 5 series. There is one chart for each variable star, except when two or more are very close. This star occupies the center of the chart, and an enclosing square of half a degree gives all the stars down to the 13th magnitude, which may be used for identification and comparison. The magnitudes and positions of these comparison stars are plotted on the chart and are also catalogued with great care and exactitude. The rest of another circumscribing square of one whole degree contains stars copied from the Bonn Durchmusterung.—Fr. Hagen's prompt construction of a chart for Nova Persei in March 1900, helped very materially towards obtaining and discussing valuable observations of this wonderful star.

Fr. Sidgreaves, Director of the Stonyhurst College Observatory from 1862 to 1868, and again from 1890 until the present, and companion to Fr. Perry in his transit of Venus expeditions and magnetic surveys, is continuing Fr. Perry's meteorological, magnetic and astronomical work and devoting himself in addition to stellar spectroscopy. "His most important investigation is fully described in his well-known Memoir (published by the Royal Astronomical Society) on the spectrum of Nova Aurigæ. * * * The novelty of the arrangement is in the absence of a slit, the star being made to drift slowly in a direction parallel to the refracting edges of the prisms. The resulting spectra are surprisingly sharp, and the exposure is much less than that required with a slit spectroscope of the same dispersion."* Fr. Sidgreaves's photographs of the spectrum of Nova Persei, 1901, and of the changing spectrum of β Lyræ, of Mira Ceti, and many other stars, have been exhibited at the Royal Society, Royal Photographic Society and the Paris Exhibition, and elicited universal praise.

In regard to comets, Father De Vico discovered eight, one of them being the well known periodic one ($5\frac{1}{2}$ years) which bears his name.

Maps of Countries.

While endeaving to christianize the heathen in foreign countries, the Jesuits of today are treading in the footsteps of their

* Professor G. E. Hale, in Astronomy and Astrophysics, No. 121, page 58.

predecessors and making themselves useful to science. Thus, the Jesuits at Zi-ka-wei "have issued numerous excellent maps either separately or as appendices to other works. The first of these classes is represented by a "Map of China at the Time of Tsch'oen = ts'ieou" (Chronicle of Confucius 722-481 B. C.) drawn by Fathers J. Lorando and J. B. P'e, the old names being in red and the modern ones in black. Then there is the "General Map of China," 1894, (100 x 73 centimeters) of Fr. S. Chevalier, which gives all the prefectures and sub-prefectures. Concerning the maps accompanying Fr. Havret's "The Island of Tsongming" in the first number of the periodical called Variétés sinologiques published at Zi-ka-wei, ex-consul H. E. Parker (an English Protestant) says: "There are two very excellent maps; one gives a picture of the whole province and is of altogether inestimable value to travelers; the other is a complete map of those parts of the Yang-tse-Kiang which flow through Ngan-Hoei." "*

"The Logerot Gold Medal of the Paris Geographical Society has been conferred upon Father Chevalier, of the Kiang-nan mission. The President of the Society in bestowing it said: "Father Stanislaus Chevalier arrived in China in 1883, and since then has devoted his learning and energy to the development of the Zi-ka-wei Observatory, near Shanghai. His remarkable studies on the typhoons of the China Seas long ago attracted the attention of the scientific world, and now the publication of his Atlas of the Upper Yang-tse appears to this Society an excellent opportunity of rewarding this modest scholar who, to the honor of France, is accomplishing this immense work in the province of Kiang-nan. The result of his long and fruitful journey through Sze-chuen allowed Father Chevalier to accomplish, between November, 1897, and March, 1898, the surveys necessary for his Atlas of the Upper Yang-tse, from I-chang-fu to Ping-shan-hien. This Atlas, consisting of two parts, containing the journey and a description, is composed of 64 plates, on the scale of 1 : 25000. We may judge of the magnitude of Father Chevalier's work when we know that, in order to compile the table of statistics astronomically fixed between I-chang-fu and Ping-shan-hien—not to speak of observations of meridional passages of stars, about 450 in number, and now of the observations between I-chang and Shanghai—he had to take over 800 altitude observations of the Sun and stars, each observation being separately calculated after a very

* Die Katholischen Missionen, Freiburg, Switzerland, Vol. 26, Sept. 1898, p. 277.

rigorous method. Thanks to the labor of Father Chevalier, we may now say that if the hydrography of the Lower Yang-tse (except that of Shanghai, due to Septime Viguier) is English, that of the upper basin is French." "*

"The Geographical Society of Paris has conferred upon Fathers Colin and Roblet, of the Society of Jesus, missionaries in Madagascar, [for their map of the country] the Herbert Fournet prize, the greatest at its disposal. It consists of a gold memorial medal and of the sum of 6000 francs. M. Alfred Grandidier, a member of the Society, and commissioned to report upon the matter, remarked on this occasion that "in the entire history of travels no second example of such a comprehensive and completed production as that of Fr. Roblet's could be found." This father carried on the topographical survey of Imerina from 1872 to 1884, all alone, and in a country the greater part of which was yet wild, under almost insuperable difficulties, and not seldom at the risk of his life. He measured 32000 square kilometers and climbed 3000 mountain heights. * * * To this enormous labor the triangulation of the Betsileo country must also be added. Fr. Colin became his assistant in 1888, and at his own initiative built in Tananarivo the first French observatory in the southern hemisphere. After testing and making sure of Fr. Roblet's results, he continued with him to the east coast the geodetic, astronomical and magnetic measurements begun in Imerina. At the call of the government both then came to Paris to complete their work. Fr. Roblet's map proved a reliable guide to the French expedition according to the testimony of Generals Duchêne and de Torcy."†

But the Atlas de Filipinas, which appeared in 1900, will probably appeal more to American readers. It comprises a series of 30 maps, which embrace about 1725 islands and 118542 square miles of measured and about 1000 of unmeasured area. An ethnographic map gives the habitat of 69 tribes, an orographic one the mountains, volcanoes and ocean depths, and another the frequency of earthquakes. Professor Henry S. Pritchett, the superintendent of the United States Coast and Geodetic Survey, remarks in his Introduction to the Atlas: "Shortly after the Philippine commissioners reached Manila it was learned that a series of maps, covering the more important islands of the archipelago, was being prepared at the Jesuit Observatory, under the super-

* Woodstock Letters, vol. 30, p. 307, November 1901.

† Die Katholischen Missionen, Freiburg, Switzerland, Vol. 27, Nov. 1898, p. 49.

vision of the director, Rev. José Algué, S. J. An inspection of such maps as had already been completed satisfied the commission that they were superior to anything hitherto published.* * * The commission conceived the idea of securing their co-operation in the preparation of a comprehensive atlas of the archipelago. * * * It is an interesting fact that the technical work was executed wholly by native Philippine draughtsmen. It was carried on under the immediate supervision of Rev. Jose Algue, S. J., Director of the Manila Observatory. The entire absence of accurate surveys of many of the islands was necessarily a serious drawback, but the Jesuits spared no pains in securing all available data, and verified them by consultation with members of the other religious orders, as well as with old residents, travelers and explorers. To the admirable work of their own Order is due practically all of our present knowledge of the interior of Mindanao."

We might also add in this connection that Fr. Secchi measured a base line in the States of the Church in 1858 and determined the length of a degree of the meridian. In 1867, as the representative of Pius IX he assisted at the Paris Conference which established the length of the meter.*

Published Works.

The Bibliothèque de la Compagnie de Jésus, new edition, in 9 volumes quarto, by Father Carlos Sommervogel, illustrates in the most convincing manner the literary activity of the Society of Jesus. But ours is the domain of astronomy only. I shall pass over the astronomical articles in popular magazines and newspapers and in technical journals, and the special publications of observatories, and shall call attention only to those works and those men that are specially eminent.

The ablest as well as the most prolific of modern Jesuit astronomical writers is beyond all doubt Father Angelo Secchi. In the Bibliothèque mentioned before the bare enumeration of the titles of his productions covers the amazing number of 19 pages quarto in double columns. In fact, his literary activity almost passes belief, and one hardly knows whether he can trust his eyes in scanning the long array of his productions, even in spite of the most exact references. He sent at least 643 communications to 14 journals.† The most important of Fr. Secchi's larger works are:

* Vox Urbis, March 1, 1903.

† Vox Urbis, March 1, 1903, but the Bibliotheque mentions 42 journals. Of these 643 papers, 133 appeared in the Astr. Nachr., 184 in Comptes Rendues, etc.

1. L'Unità delle Forze Fisiche, Rome, 1864. It has gone through two Italian, one German and one French editions.

2. Le Soleil, Paris, 1870. The second edition appeared in 1875. It has been translated into German and Spanish.

3. Le Stelle, Milan, 1877. It was translated into German and French.

4. A treatise on cosmography for the use of schools, and

5. Elements of Terrestrial Physics, both in Italian, the latter a posthumus publication, 1879.

Father Secchi was equally active in physics and in meteorology, and his large meteorograph, described in Ganot's Physics, merited for him the Grand Prize (100000 francs) and the Cross of the Legion of Honor at the Paris Universal Exposition of 1867. It was conferred upon him by the hand of the emperor Napoleon III, in presence of the emperors of Russia and Austria, and of the kings of Prussia and Belgium. The emperor of Brazil sent him a golden rose as a token of his appreciation.

The "Atlas Stellarum Variabilium" by Father Hagen, of Georgetown College Observatory is "the most important recent event in the variable star world."* "It will without doubt become in time an indispensable requisite of the library of every observatory, just as the Bonn maps have become."† Professor E. C. Pickering, of Harvard College Observatory, esteemed the Atlas so highly that he obtained from Miss Catherine Bruce, the great astronomical benefactress, a donation to the printer to enable him to undertake the work, and he is also endeavoring to secure the presentation of a 12-inch equatorial to Fr. Goetz of Bulawayo, (Rhodesia), South Africa, for the continuation of Fr. Hagen's charts to southern stars.‡ Fr. Hagen has also become a great factor in the mathematical world by his "Synopsis der Höheren Mathematik" in four volumes quarto.

Less well known perhaps, but not the less important in their own sphere are the books "Astronomisches aus Babylon" by Fathers Epping and Strassmaier, and "Die Babylonische Mondrechnung" by Fr. Kugler (Freiburg, 1900). "It is well known that the investigations made by the Jesuit Father Epping (in company with the Assyriologist Father Strassmaier) upon many Babylonian astronomical bricks have had as a consequence that

* Popular Astronomy, No. 81, p. 50.

† Ernst Hartwig in V. J. S. vol. 35, p. 51.

‡ "A Plan for the Endowment of Astronomical Research," p. 12, (reviewed in Popular Astronomy No. 106 (Jun.-Jul. 1903) p. 352).

the scientific level upon which the history of astronomy had formerly placed the Babylonians, must be taken considerably higher. * * * Epping's investigations * * * now receive a very valuable extension through the labor of Father Kugler, of Valkenberg, Holland. * * * From our communication concerning the work of Father Kugler it may be inferred of what great importance his book is to the history of astronomy. Even if later discoveries made upon the Babylonian bricks should perhaps modify one or other view of the writer, the care and diligence with which he went to work stamp his book as indicating a very considerable advance upon Epping."*

"Die Gravitations-Constante, die Masse und mittlere Dichte der Erde nach einer neuen experimentellen Bestimmung," Vienna, 1896, by Fr. Carl Braun, of Mariaschein, Bohemia, represents about eight years of patient work and "bears internal evidence of great care and accuracy, and he obtained almost exactly the same result as Professor Boys.† Fr. Braun carried on his work far from the usual laboratory facilities, far from workshops, and he had to make much of his apparatus himself. His patience and persistence command our highest admiration."‡

"Ueber Kosmogonie vom Standpunkte christlicher Wissenschaft, nebst einer Theorie der Sonne und einigen darauf bezüglichen philosophischen Betrachtungen," by Fr. Carl Braun. "This problem, mighty in every respect," says Dr. Förster,¶ "is treated from almost all points of views with clearness and impressiveness. One could hardly at this time find in any other book all the essential features of a theory of the Sun collected together in such a directive manner." Fr. Braun is at present at work upon the third edition.

Conclusion.

To conclude. While I realize that I have not said all that was to be said upon the subject in hand, on account of not having access to all, nor even to the greater part, of modern astronomical literature, nor all the standard journals, I think I have said enough to convey to the reader a pretty fair idea of what the Society of Jesus has done in the field of astronomy. The cultivation of this field is only secondarily an object of the Order, and

* F. K. Ginzel in V. J. S. vol. 35, pp. 256-273.

† That is, the Earth's mean density $= 5.52760 \pm 0.0013$.

‡ Recent Studies in Gravitation, Professor John H. Poynting, D. Sc., F. R. S., Proceedings of the Royal Institution of Great Britain, vol. XVI, part 2, Nov 1901, reprinted in Annual Report of the Smithsonian Institution, 1902, p. 203.

¶ V. J. S. Vol. 25, 1890, p. 56.

is the work rather of individual members or colleges than of the whole Society.

ERRATA IN PART I.

For Tyrnan read Tyrnau.
" Brensing read Breusing.
" 1653 and 1655 (Riccioli's Works) read 1651 and 1665.

CREIGHTON UNIVERSITY OBSERVATORY,
OMAHA, Nebr.

THE DOUBLE CANALS OF MARS.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY

A few years ago the doubling of the Martian canal system was generally admitted by astronomers as an accepted fact. Latterly however doubts have begun to arise with regard to it. It was shown by the writer, in the Harvard Annals XXXII, 149, that accepting the results of Schiaparelli, Flammarion, Antoniadi and Lowell, the double canals had this curious property, namely, that their linear separation was inversely proportional to the diameter of the object-glass of the telescope, and directly proportional to the distance of the planet.

It was then suggested that some one who was able to see the duplication of the canals, which the writer has never been able to do, should make measures of their separation, using different apertures in front of the telescope upon the same night. This has now been done by Professor Lowell, Bulletin No. 5, Lowell Observatory, and a recent examination of his work has shown that he has brought out some very instructive results.

In the first place as far as he is concerned it is evident that the separation of the canals is independent of the aperture of the telescope employed. Secondly, he has found that the duplication of the canals can be seen with surprisingly small apertures. Thus with six inches he divides the three double canals Euphrates, Hiddekel, and Gihon when their components were separated only 0″.27, 0″.26, and 0″.28 respectively.

It was found by Dawes that an objective one inch in diameter could separate (not merely elongate) two equal stars 4″.56 apart. A 6-inch objective should therefore separate stars at one-sixth this distance, or 0″.76. Experiments made at Cambridge with a 15-inch aperture* showed that in order to divide two

* Harvard Annals XXXII, 149.

lines drawn in ink on white paper, they must be separated by an angle of 0″.42. For a 6-inch objective the required separation would therefore be 1″.05.

An analagous experiment may be readily repeated without instruments. Draw two lines in ink 1 millimeter, or one twenty-fifth of an inch apart, on white paper. Placed at a distance of ten feet they can just be divided with the naked eye. Their separation will be 70″. The diameter of the pupil of the eye in a brightly lighted room is about one-tenth of an inch. If we can conceive the pupil enlarged sixty times, which is what is practically done by a 6-inch telescope, we should be able to separate the lines at one-sixtieth of this distance apart, or at 1″.15.

Summarizing our results, and applying them to the case of a 6-inch telescope, we find from Dawes' experiments, confirmed universally by astronomers, that two stars could only be separated when as much as 0″.76 apart. The less the contrast the more difficult the separation. Therefore for black lines on white paper we need a greater separation than in the case of the stars. Our telescopic experiments with black lines indicate that the angle must measure 1″.05. Our naked eye experiments make the angle 1″.15. In the case of Mars, Professor Lowell can detect the duplication when the separation is only 0″.26. This would be equivalent in the case of the naked eye experiment to separating two lines one millimeter apart at a distance of forty feet. This the reader will find is quite impossible,

The writer hesitates to believe that Professor Lowell can separate two actual lines which are so much nearer together than the limit for other observers, and thinks therefore that what he sees must be some optical illusion.

REPORT ON THE REQUIREMENTS FOR THE MASTER'S DEGREE.*

At the Christmas meeting of the Chicago Section of the American Mathematical Society, held January 2 and 3, 1902, a committee was appointed to consider and report a scheme of requirements for candidates proceeding to their second degree, with mathematics as their major subject. It was thought that a mathematical program generally adopted in the central west would facilitate the migration of students from one institution to another, thus permitting students to take portions of their mathematical work at different institutions; that it would tend to preserve the value of the master's degree by making it represent equivalent attainments; and that it would enable the smaller colleges better to arrange their elective studies, so that students intending to make mathematics a specialty could, by a proper selection, obtain sufficient mathematical training to enter at once after graduation upon work which might be counted toward the master's degree.

This committee through its chairman sent a circular letter of inquiry to seventeen institutions of the central west, including all of the state universities from Ohio to Colorado, and others which may be regarded as of the same rank, or in which the mathematical department is especially strong. This letter invited a free discussion both as to the actual practice in these institutions and as to what might seem desirable as a mathematical program covering both the undergraduate work and that leading to the second degree. As a basis of undergraduate work it

* For some time there has been considerable discussion concerning the requirements that should be made, in mathematics, for entrance to college, for the Bachelor's degree and also for the Master's degree. The reason for this has been the lack of uniformity which it obtains in the best colleges East and West. In order to make it possible for students who wish for any reason to be transferred from one institution to another without uncertainty or hardship, a very strong sentiment in favor of uniformity of requirements is setting in this direction.

We call attention to this article more especially now because it will help to answer some of the questions that come to us frequently, asking what preparation is necessary in mathematics that students may later pursue the study of astronomy most advantageously.

This scheme of work which was presented to the Chicago Section of the American Mathematical Society and recommended for publication Jan. 1, 1904, covers this ground of preparation very thoroughly. We deem it an excellent guide for any student who wishes a thorough foundation in the mathematics for most of the branches in science which are carried forward to professional standards in the best scientific schools in the United States.—[EDITOR.]

was assumed that the student enters college with a thorough knowledge of algebra through quadratic equations and with plane and solid geometry. It was also assumed that the master's degree is to be conferred upon the successful completion of one year of *graduate* work, and that the college course covers four years of academic training. The scope of the inquiry is shown by the questions asked. They were as follows:

1. What should be the *minimum* acceptable time devoted to undergraduate mathematics?

2. What subjects should be included in the undergraduate course in pure mathematics? How much time should be devoted to each?

3. Should applied mathematics be required? What subjects, and how much?

4. Should French and German, one or both, be required? If only one, which one?

5. Should the candidate for the master's degree be required to pass a more rigorous examination than is required of the undergraduate?

6. Should a thesis be required?

7. Should the graduate work leading to the master's degree be confined to one, two, or three departments?

In order to make it more easily interpreted in the particular system of accrediting subjects at the several institutions, the committee has formulated its report in terms of recitation hours; thus a subject coming five times a week for one year of 36 weeks is assigned 180 hours.

After canvassing the replies from the institutions mentioned above, the committee submits the following mathematical program as giving the *minimum* preparations which should be accepted as sufficient for entering upon graduate work. It further reports a program of graduate work, which is recommended as the minimum basis for granting the second degree.

1. The minimum time devoted to mathematics in the undergraduate course should be 540 hours. This means that at least one-fourth of the student's undergraduate work should be devoted to the study of mathematics, if he expects to secure his master's degree in mathematics after one year of resident graduate study. Whether this amount, or more, be taken, it is recommended that it be distributed throughout the four years of the undergraduate course, to the end that the continuity of his mathematical study may not be disturbed as the student passes from his undergraduate to his graduate work.

2. The 540 hours mentioned above should be distributed substantially as follows:

I. College algebra, including the elements of determinants; trigonometry; and analytic geometry, including an introduction to solid analytic geometry. 180 hours.

II. Differential and integral calculus, differential equations, and mechanics. 225 hours.

III. Advanced algebra, including the general theory of equations; modern analytic and synthetic geometry, or solid analytic geometry. 135 hours.

3. The undergraduate instruction, especially in its earlier stages, should, by well chosen illustrations and applications, be kept in close contact with the physical sciences. Logical statement and proofs of theorems should always be delayed until their meaning is made familiar by application to special cases, and the problems considered for such purposes should be such as arise naturally out of concrete experiences. Whenever possible, a physical or a graphical solution of the problem should be given. In all mathematical teaching a clear comprehension of ideas and their correlation are of prime importance. In the earlier stages of any subject these can in general be best secured through the physical senses and by a method analogous to that of the general science laboratories. Abstract analysis should arise naturally in the effort to devise the most precise, clear, and convenient method of formulating and expressing the results of experiments and observations; and only in the later stages should it become an object of thought and investigation.

4. Upon the basis of the preparation indicated above, it is the opinion of the committee that the work leading to the master's degree should include at least 270 hours selected from the following groups of subjects. The selection should in any case include subjects from at least two of the three groups.

I. GEOMETRY.

Projective geometry.
Modern analytic geometry, algebraic curves and surfaces.
Application of calculus to twisted curves and surfaces. (Differential geometry).
Solid analytic geometry.
Descriptive geometry (Darstellende Geometrie).

II. ANALYSIS.

Theory of equations.
Advanced calculus.
Theory of functions.

Differential equations.
Theory of numbers.
Invariants.

III. APPLIED MATHEMATICS.
Analytic mechanics.
Mathematical astronomy.
Mathematical physics.
Mathematical theory of probability.

This arrangement provides that the candidate, in case he enters upon his graduate work with the mininum mathematical preparation indicated above, and hence having a broader *general* training in his undergraduate course, should be required to take at least two-thirds of his year's graduate work in pure and applied mathematics. On the other hand, as it may be assumed that the student entering upon his graduate work with a larger mathematical credit than this has had less *general* training in his undergraduate course, it is the opinion of the committee that he should be permitted to take as much as one-half of his work in departments other than mathematical, providing, however, that the minimum requirement in mathematics indicated above is also fulfilled.

5. The candidate for a second degree should enter upon his graduate work with a sufficient knowledge of German to enable him to read easily mathematical works in that language. The committee thinks it very desirable that he should have also a reading knowledge of French.

6. It is the opinion of a large majority of the institutions with which the committee has corresponded, as well as the opinion of the committee, that in all cases a thesis should be required. This may not, and in most cases cannot, be in the strictest sense original research. It is, however, a convenient way of testing the student's ability to carry on independent investigation, and gives him an excellent preparation for research work later.

7. The examination of the candidate for a master's degree should be distinguished as to rigor and perhaps as to character from the ordinary term by term examination of the undergraduate student. Two plans are proposed, either of which, or a combination of the two, is commended.

(*a*) That the candidate be permitted to take the term by term examinations, as in the case of undergraduates, but that he should be expected to earn a higher grade than would entitle him to pass in case he were an undergraduate.

(*b*) That he be required to pass a final examination at the

time of taking his degree covering all of the subjects included in his graduate course.

The committee finds a great diversity of practice as to the amount of mathematics which is made the basis of graduate work at the various institutions mentioned at the beginning of this report. It believes, however, that the program outlined above is within the reach of all. Furthermore, upon comparison with the requirements at several of the leading American universities, it was found that the minimum requirements which are here recommended are in substantial accord with the minimum requirements for the master's degree at these institutions.

It is the thought of the committee that, as meeting the above requirements in preparation for graduate work, the work of no institution claiming college grade should be accepted unless the major part of the work in preparation has been taken under the direction of mathematical instructors who have themselves done the equivalent of the work here outlined for the master's degree in mathematics.

By the adoption of the above mathematical program by the institutions represented in the Chicago Section, it is believed that a substantial service would be rendered the study of mathematics in the central west, not only by securing the advantage of uniformity in granting the second degree, but by elevating in some cases the standard upon which the degree is granted, and perhaps more than all else by giving to the small college, aiming to prepare for graduate work, a standard by which it may best arrange its elective system.

C. A. WALDO, Chairman,
E. J. TOWNSEND,
OSKAR BOLZA,
Committee.

TIME.*

FOREST R. MOULTON.

INTERRELATIONS OF THE SCIENCES.

The evolution of the method of scientific inquiry has long been in the direction of specialization. The many new fields which have been opened up, as well as the remarkable advances which have been made in those which have longer been the subjects of investigation, have made these changes necessary. It has become practically impossible for a single individual to obtain such a general knowledge of different sciences which are not most in-

* Reprinted from *Journal of Geography*.

timately related, and at the same time such a command of necessary details and such expertness in technique that he can hope to make important contributions to them. This condition of affairs has developed a class of specialists whose achievements are justifying their methods.

There is, however, another sort of work, frequently of the highest importance, which consists in coördinating the results obtained in special fields. Indeed, as a general rule the importance of a fact is directly proportional to the number of its essential relations with other facts. Thus, the Newtonian law of gravitation and the law of the conservation of energy have played rôles of unparalleled importance in modern scientific discoveries because of their universal relations to physical phenomena. Therefore from a purely scientific point of view work in correlating facts may be of as much importance as any.

Likewise, in considering education from the utilitarian point of view, it is at once apparent that a knowledge of facts is of no greater importance than a just appreciation of their relationships. The ability to anticipate events, which is of so much importance in business and public life, consists to a very large extent in being able to draw conclusions from data which are available to all. Or, simpler still, ordinary common sense, which is one of the most valuable possessions one can have, doubtless consists largely in a just estimation of the relative importance of things.

It appears, therefore, that coördination is a valuable part of scientific work, and also that the average person should not only know facts but should thoroughly understand their relations as well. Everyone knows that the most valuable and lasting things he ever obtained from any teacher were not the few facts he may have been taught, but that they were the judicial attitude of mind and the intellectual balance which characterize good thinkers. It follows from these considerations that the average teacher, while being proficient in the subjects he teaches, should have a good knowledge of related subjects; that he should realize that the divisions of science are more or less artificial and for convenience; that, to obtain the best results in one subject, the points of contact with related subjects should be shown; and, above all, that the primary object is to develop the faculties of the student rather than to teach any subject. In accordance with these ideas this paper, as well as those which may follow, will be devoted to questions lying for the most part on the border lines between Astronomy on the one hand, and Geography and Geol-

ogy on the other, and an attempt will be made in them to show some of the relations existing among these sciences.

Time and its Measurement.

Formal definitions of what time is are frequently given, but they are usually mere combinations of words which mean nothing to the reader if he has not already a satisfactory idea of what is meant by the term. In fact, a little thought will convince one that it is not easy to define time in other terms, nor is it a simple matter to state what we know about it. It will not be profitable to enter into a discussion here respecting its existence in the abstract. It is sufficient to observe that if a number of events are under consideration the relations of their occurring are such that everyone can arrange them in the same unique order. That is, in the case of two events A and B, everyone can say that A existed when B did not exist and that when B existed A existed also; or, we have a definite idea of the order of their occurring, and so on for any number of events. The point to be noticed here is that there is universal agreement in the question of order, at least in cases which offer no observational difficulties.

It must not be inferred, however, that the question of order is all that is involved in time, for time is supposed to be measurable, while order is not. The difficult question relates to the intervals between events. We have a more or less vivid impression that there is an interval between two events, which is probably induced by the consciousness that a number of other events have occurred between them, such as something we can hear or see, or, perhaps, such physiological processes as the number of heart beats or the number of mental acts. But this impression is not of the same certain character as the idea of order. If many persons observe two events A and B and then two others C and D, they will not in general agree among themselves as to the relation between the interval A B and the interval C D. The estimate of the interval in the two cases depends upon a multitude of things such as the comfort of the individual, and his physical and mental activity. Everyone remembers how a few days of travel, especially when he was young, amid unfamiliar surroundings, have seemed like ordinary weeks of time, and how he marveled on his return that he did not look as strange to his friends as they did to him. The multitude of new experiences gave the impression of great length of time. For similar reasons short dreams often seem to fill hours or even days of time. It is clear

that such indefinite methods of estimating time as these are of very little scientific value.

It will be found that the estimates of various observers agree more nearly the more fully they base them upon counts of the occurrences of simple phenomena. It will be perceived at once that this implies that they have supposed that the simple events observed have occurred at equal intervals, or perhaps in rare cases in unequal but simply related intervals. This being the basis of our ideas of intervals of time, and the only way of measuring them, it remains to simplify the method and make it precise. To do this it is only necessary to select some event which is repeated an indefinite number of times in such a manner that it will occur after, in a sense of order, any event of another kind, and such that it can be universally observed.

It may be stated without further remarks that equal intervals of time are defined by Newton's first law, or axiom, of motion, which affirms that *a body subject to no forces moves uniformly in a straight line.* That is, two intervals are equal by *definition* if a moving body which is subject to no forces passes over equal distances in them. It is impossible practically to realize the condition stated in the law, but the indirect consequences of it are of great simplicity. It follows from this and the other laws of motion that the Earth rotates uniformly. (The possible corrections to this statement are discussed in the next section). Therefore the rotation of the Earth becomes not only the practical measurer of time but as a result of Newton's laws, the definition of what is meant by equal intervals of time. If it were not a definition its correctness could be tested. But it is well known that if anything, such as a clock, disagrees with the rotation of the Earth, it is at once assumed to be wrong. The only sensible method of testing it would be to compare its rotation with some other simple consequence of Newton's laws, such as the rotation or revolution of some other planet. If there were a disagreement it would show that one or the other of the bodies is subject to effective exterior forces not taken into account.

It will be observed that this definition of duration, which is at the bottom of every method of measuring time, does not depend upon any particular conception of time in the abstract; indeed, if any such thing as time independent of physical phenomena exists, it is quite possible that this definition may disagree with it.

Possible Changes in the Standard of Time.

As has been stated, time is practically measured by the rotation of the Earth, while the definition of equal portions of it is

contained in Newton's first law of motion. If the forces to which the Earth is subject cause it to rotate non-uniformly on the basis of the Newtonian laws, then the practical standard of time will be variable with respect to that basis. Are there forces at work upon the Earth (the Newtonian law will henceforth always be assumed to give the standard) which change its rate of rotation?

The Earth is rotating in the luminiferous ether and a considerable quantity of meteoric matter. The latter, if not the former, offers some resistance to its motion, and causes it to rotate more slowly, just as friction causes the rotation of a top to die out. But this resistance is exceedingly feeble and will produce no measurable results for thousands of years. It would produce sensible results in the revolution of the Earth much more quickly, but even there the effects are inappreciable.

As the Earth loses its interior heat it undoubtedly shrinks a little. The effect of this change in size is to make it rotate faster, but the increase of motion is exceedingly slight.

The Sun and Moon generate tides in the Earth which move around in the westward direction. Since the Earth rotates eastward the impact of these tidal waves on the shores and the friction they encounter in passing along the oceans retard the rotation of the Earth. These effects are again very small.

Changes in the form of the Earth such as the elevation and subsidence of continents, or the less important alterations produced by erosion, or the evaporation of quantities of water and subsequent condensation in another latitude produce slight changes in the rotation of the Earth. In fact, if any mass is moved so that its distance from the axis of the Earth is changed, and no compensating shifting is made, the rate of rotation of the Earth is altered.

The important question is whether these changes are sensible. Those due to the causes last mentioned are not only exceedingly minute but they nearly, if not exactly, balance each other. Those due to the first and third causes are constantly in the same direction while that due to the second cause continually opposes the ". It is very difficult to determine their precise effects quantitatively, but they are certainly so minute that they do not change the length of the day by a second in ten thousand years. Therefore, if one be divided by the number of days in ten thousand years a number will be obtained which will be greater than the difference between any two successive days when it is expressed in seconds. It is evident that this is an interval so small that it is absolutely inappreciable; hence the rotation of the Earth may be taken as

giving the same results within the limits of observation as Newton's first law of motion.

One difficulty remains to be mentioned which might be easily overlooked. It has been tacitly assumed that it is possible to determine when the Earth has completed a rotation, but this is clearly impossible unless a fixed direction in space, not parallel to the Earth's axis, is known. Now there are no known fixed points or lines in space by means of which a fixed direction can be determined, but it is *assumed* that the stars do not, on the average, move in any angular direction with respect to the Earth. Hence it is necessary to admit the assumption, which of course appears most reasonable, in order to make use of the rotation of the Earth as a means of measuring time.

It should be remarked that if one should attempt to apply the definition contained in Newton's law a corresponding difficulty would be encountered. In this case it would be necessary to determine in some way a fixed point in space from which to measure the distances, a difficulty which is less easily overcome by any reasonable and practical assumption.

Sidereal Time and Solar Time.

Sidereal time is measured by the rotation of the Earth with respect to the stars, and solar time by the rotation of the Earth with respect to the Sun. Because of the Earth's revolution around the Sun, the Sun appears, as seen from the Earth, to move eastward among the stars, completing a revolution with respect to them in a year. Now suppose the Sun and a star are on the meridian at a given time; after a certain interval the Earth will have turned so that the star is again on the meridian. This interval constitutes the length of a sidereal day, all of which are almost exactly of the same length, as has been explained above.

But at the end of this interval the Sun will have moved nearly a degree eastward and will therefore lack a little of being on the meridian. It takes nearly four sidereal minutes for the Earth to turn enough more to bring it on the meridian. When it has arrived there a solar day has elapsed.

Shortest Solar Days and Longest Solar Days.

The Earth moves faster when it is near the Sun than when it is more distant; consequently the apparent motion of the Sun among the stars is not uniform. Besides this the Sun has a northward and southward motion, which at times decreases the eastward motion. Hence, for these two reasons, the apparent eastward motion of the Sun among the stars, which alone makes the

solar day longer than the sidereal, is irregular; and there is a corresponding variation in the lengths of the solar days. The lengths of the days vary in quite a complicated manner, though the extreme difference is not very large.

The longest day in the year is December 22d (it may vary by a day from this date because of the leap year once in four years) which is $4^m\ 26^s.5$ longer than the sidereal day when the difference is expressed in sidereal time. Thus, the day which has the least time of sunlight for positions in our latitude, and which in ordinary speech is spoken of as the shortest day in the year, is actually the longest from the time the Sun is on the meridian until the Sun is on the meridian again. From December 22d the solar days constantly decrease in length until March 26th, when they are only $3^m\ 38^s$ longer than a sidereal day. From March 26th the solar days increase in length until June 20th, when they are $4^m\ 9^s.5$ longer than the sidereal day. From June 20th the solar days again decrease in length until September 17th, which is the shortest day in the whole year, being only $3^m\ 35^s.2$ longer than the sidereal day. The difference in length between the longest day and the shortest day is therefore about $51^s\ 3$ of sidereal time. From September 17th until December 22d the solar days constantly increase in length.

The average length of the solar days, which is $24^h\ 3^m\ 56^s.556$ in sidereal time, is called the mean solar day. This is the time in actual use, being divided into twenty-four mean solar hours, and from this point on all references to time will be to mean solar time. Mean solar days are all of the same length, with the same approximation that sidereal days are of the same length, and ordinary time-pieces are made to keep this time as nearly as possible. It would be very difficult, if not impossible, to construct a clock which would keep true solar time with any high degree of accuracy.

Local Time and Standard Time.

The mean solar time of a place is called its local time. All places having the same longitude have the same local time, but places having different longitudes have different local times. In going around the Earth, a distance of about 25,000 miles, the difference is twenty-four hours; consequently at the Earth's equator, seventeen miles in longitude correspond to about one minute in time. In our latitude the circumference of the Earth along a parallel of latitude is considerably less, and twelves miles correspond to about one minute in time. Hence the difference in local

STANDARD TIME BELTS IN THE UNITED STATES.

time between places on the Atlantic coast and those on the Pacific coast, which are separated by nearly 3,000 milles, is about four hours.

In order to avoid the endless confusion, and in some cases danger, that would follow if places comparatively near together should have sensibly different time, it has become quite customary for all places which do not differ more than about half an hour in local time from that of some convenient meridian to use the local time of that meridian. Thus, while the extreme difference in local time of places using the same time is about an hour, the error in either of them is only half an hour. In this manner a strip of country about 720 miles wide east and west uses the same time, and the next strip of the same width an hour different, and so on. This time is called *standard time*, and it differs from the local time except in one meridian in each strip.

In the United States there are four hours of standard time used. The eastern portion uses Eastern Time which is the local time on the 75th meridian west from Greenwich, which runs through Philadelphia. At places east of this meridian it is later by local time than by standard time, the difference being about one minute for twelve miles. Thus at New York, on the basis of local time, standard clocks are four minutes slow, at Boston sixteen minutes slow, etc. At places west of this meridian, but in the

eastern time division, standard clocks are correspondingly fast, the difference being nearly twenty minutes at Pittsburg. West of Buffalo, and a line running irregularly northward and southward through it, Central Time, which is the local time of the 90th meridian, is used. This meridian passes very near St. Louis. Standard clocks of places east of this are slow, the difference being nearly twenty-five minutes at Cincinnati and about ten minutes at Chicago. The western limit of Central Time extends through the Dakotas and northwestern Texas. The next division westward is called Mountain Time, and is the local time of tht 105th meridian, which passes through Denver. This division of time is used west as far as Ogden. The next is Pacific Time, the local time of the 120th meridian which is about 100 miles east of San Francisco. As the intervals between the standard meridians are in all cases 15 degrees of longitude, which equals one hour of time, there is a difference of one hour between one division of time and the next; If the exact divisions were used the boundaries between one time division and the next would be meridians 7.5 degrees east and west of the standard meridians. As a matter of fact the railroads, which furnish local time to most places, and to which most people look for correct time, use dividing points between the divisions of time according to their own convenience. It obviously would be unwise to have railroad time change during the run of a given engineer. Hence railroad time changes at the most convenient place near the boundary of the time division, that is, at the nearest point where engineers change. As a result, the boundaries of the several time divisions as used are very irregular, and vary in many cases very strikingly from the standard divisions. (See map page 398).

Although this very convenient system was adopted in 1883 and is in universal use by railroads, yet many people, and even schools, persist in creating confusion by using local time. In some cities one has to allow a margin of twenty minutes in appointments because of the uncertainties due to this chaotic state. It is perfectly clear that standard time is in every respect just as good as any and that it has the immense advantage of being uniform over large sections of country. Let educated people, who above all others should consciously direct their activities in the direction of reforms, not hinder advances inaugurated by commercial interests; instead of being paralyzed with conservatism let them become the leaders of progress.

Distribution of Time.

The accurate practical determination of time and its distribu-

tion are problems of much importance. There are several methods of determining time, but the one in common use is to observe the transits of stars across the meridian, which gives the sidereal time, and then, from the mathematical theory of the motion of the Sun, to compute the mean solar time. It might be supposed that it would be simpler to observe the transit of the Sun, but it is not so. In the first place it is much more difficult to determine the exact time of the transit of the Sun's center than it is the time of the transit of a star, and it occurs but once in twenty-four hours while many stars may be observed; in the second place, it gives true solar time instead of mean solar time, and its correction is as difficult as that required in the other method.

It remains now to explain how time is distributed from the observatories where the observations are made. The chief source of time for railroad and commercial purposes is the Naval Observatory at Georgetown Heights, Washington, D. C. There are three clocks keeping standard time at this observatory. At night the errors of the three clocks are found from observation, and, after applying this correction, the mean of the three is taken as giving the true standard time for the succeeding twenty-four hours. At five minutes before noon eastern time the Western Union Telegraph Company suspends its ordinary business and throws its lines into electrical connection with the standard clock at the Naval Observatory. An arrangement is made so that the sounding key makes a stroke every second during these five minutes except the twenty-ninth second of each minute, the last five seconds of the first four minutes, and the last ten seconds of the fifth minute. This gives the opportunity to make ten determinations of the error of a clock at any point. To simplify matters clocks are made which are automatically regulated by these signals, and there are at present more than 30,000 of them in use in this country.

These noon signals also operate time balls in fifteen ports in the United States. This device consists of a large ball being dropped at noon, eastern time, by means of electrical connection with the Naval Observatory, from a considerable height, at conspicuous points.

The time signals are sent out from the Naval Observatory with an error usually less than two-tenths of a second, but this is frequently considerably increased by the system of relays which must be used to reach great distances. Probably the greatest source of error, except in the case of those automatically regulated, is in setting the clocks by the signals.

The time service just described reaches directly nearly all parts of the country east of Ogden. West of Ogden time is distributed in the same manner from the Mare Island Navy Yard, California. Besides the government sources, the Allegheny Observatory furnishes time to the Pennsylvania railroad; the Goodsell Observatory, of Northfield, Minn., to the Great Northern, the Northern Pacific, the Great Western and the "Soo" lines; the Lick Observatory, to the Southern Pacific system. Many other observatories furnish time for local purposes, and practically every one keeps its own time.

THE LARGE NEBULOUS AREAS OF THE SKY.

H. C. WILSON.

As bearing upon the question of the origin of our solar system and of other stellar systems, the existence at the present time of enormous areas of exceedingly faint, diffuse, nebulous or cloud-like matter in the heavens is of important significance. According to the "Nebular Hypothesis" the Sun, planets, and stars have been formed by the aggregation and condensation of just such matter, which is supposed to have originally filled all space. If this hypothesis be true, it would be strange if there were not still much of the original cosmic matter still scattered through the interstellar spaces. In fact we do find several thousand little patches of faint cloud-like light distributed here and there over the sky and we call them, for want of a better name, nebulæ. The spectroscope shows many of them to be composed of glowing gas, a mixture possibly of hydrogen and some unknown gases. Others yield the spectra of glowing solids and we infer them to be either clusters of stars so remote that the individual stars are beyond the limit of vision with our telescopes, or immense clouds of small particles of matter glowing from some unknown cause.

All of the nebulæ, so far as yet determined, are at vast distances from us, so that although they are really enormous in extent they cover only small areas of the sky. The largest is the Great Nebula of Andromeda, which covers an oval area about 2° long and 1° wide.

In addition to the nebulæ which can be seen or photographed, with comparatively definite outlines, there are a few much larger patches of very diffuse, exceedingly faint light in certain parts of

the sky. They are too large and faint for their outlines to be detected with a telescope, and they cannot be photographed with an instrument of too great focal length. They require a camera of great light-gathering power, short focus, and wide, flat field. There is but little contrast between their light and that of the general illumination of the sky, produced by the reflection of the starlight from dust and frost particles in our atmosphere, so that a very little haze obliterates them entirely.

The most remarkable regions of this kind now known are in the constellations Taurus, Orion and Scorpio and photographs by Pickering, Barnard, Wolf and the writer of this note agree in the main details of the nebulosity in these regions, so that there can be no doubt as to its existence. Around the Pleiades in Taurus the nebulosity extends about 5° to the north, west and south, and 7° or 8° to the east from the group of stars. In Orion nearly the whole constellation is involved in a vast field of nebulosity, of which the "Great Nebula of Orion" is but the central part.

Sir Wm. Herschel saw fragments of these nebulosities in his sweeps of the heavens and recorded the positions of 52 regions of the sky in which he saw, or suspected that he saw, very faint milky light in the background of the stars.

Seven of Herschel's regions are in Orion and six in Taurus, but only one of those in Taurus is in the vicinity of the Pleiades which has been so much photographed. Curiously, in the spot indicated by Herschel the nebulosity is not so bright as it is in the same declination about 20 minutes toward the west, but if I identify the location correctly, it is in a space almost void of stars, so that the faint light would be more noticeable there than in other regions where the stars were more numerous. In Orion Herschel's regions are found to coincide closely with some of the brighter parts of the nebulosity shown by the photographs, but the latter show a far greater extent than Herschel was able to detect.

Herschel says of his observations: "When these observations are examined with a view to improve our knowledge of the construction of the heavens, we see in the first place that the extensive diffused nebulosity is exceedingly great indeed; for the account of it, as stated in the table, is 151.7 square degrees; but this, it must be remembered, gives us by no means the real limits of it, neither in the parallel nor in the meridian; moreover, the dimensions in the table give only its superficial extent; the depth or third dimension of it may be far beyond the reach of our telescopes; and when these considerations together are added to

what has been said in the foregoing article, it will be evident that the abundance of nebulous matter diffused through such an expansion of the heavens must exceed all imagination."

In these words Herschel expressed no doubt of the reality of what he saw, and if he could have seen the photographs which I have at hand as I write of the Pleiades and Orion regions he would have felt that his words were abundantly justified. Either of these two regions contains more than the 150 square degrees of nebulous area which he assigned to his 52 regions.

On the other hand Dr. Isaac Roberts, the foremost of the English celestial photographers, who has done marvelously good work in photographing the nebulæ and star clusters, after photographing the entire list of 52 nebulous regions, says, in *Monthly Notices*, R. A. S., LIII, 1, "Of the fifty-two nebulous regions described by Herschel, the photographs show diffused nebulosity on four of them only." The four are a part of the Great Nebula of Andromeda, the region around ζ Orionis, and two parts of the "America" nebula in Cygnus, all comparatively bright and well known. Dr. Roberts failed to get any of the nebulosity around the Pleiades and also the greater part of that in Orion. This failure instead of being totally discouraging leads us rather to believe that Dr. Roberts' work was not done under the most favorable conditions, and that therefore there is hope that under better conditions more of these regions given by Herschel may be proved by photographs to be nebulous.

I have been much interested in these enormous nebulous areas for several years past and have obtained a number of photographs, especially of the Pleiades region, with our Brashear 6-inch star-camera and with the 2½-inch Darlot lens, which show the nebulosity quite distinctly. Two of the Pleiades' photographs were reproduced by the half-tone process in POPULAR ASTRONOMY for Feb. 1899, Plate II. A later photograph, taken on the nights of Nov. 7 and 8, 1899 with the six-inch camera and a total exposure of seven hours, is herewith given (Plate XI). It shows more of the nebulosity than the other two, verifying nearly all that was shown in them and adding considerably to the extent of the nebulosity especially to the eastward. The darkening toward the lower right hand corner of the plate is due to the too narrow opening of the dome, the field being partially cut off in that direction. The Darlot camera, the field of which was clear in that direction, shows a considerably greater extension of the nebulosity to the southwest. In fact it does not appear certain that the limit of the nebulous area has been

reached in any direction. It fades from view toward the edges of the field, partly from a real lack of intensity and partly because the light-gathering and defining power of the lenses declines the farther the object is from the center of the field.

The area covered in the reproduction extends from about 3^h 25^m to 4^h 5^m in right ascension and from 20° to 27° 30′ in declination. The bright star about three-fourths of an inch to the right of the upper left hand corner of the plate is ψ Tauri. Almost directly below this and about an inch from the bottom of the cut is A Tauri. These are the only stars in the region, outside of the Pleiades group, which are as bright as the fifth magnitude.

The distribution of the nebulosity is not at all uniform throughout this region, although plainly the whole region is filled with it. There are darker spaces, lanes or channels scattered through it which give it a vague resemblance to the Great Nebula of Orion. It will be noticed that there is very little halation around the stars, so that the blotting out of the principal stars in the Pleiades group is due chiefly to the dense nebulosity which surrounds them. This is greatly intensified in the method of making the reproduction. On the original negative the stars are all quite sharp and clear cut and much detail is shown in the nebula within the group. I presume that by manipulation in printing, shielding all of the plate except the bright group, one might bring out these stars in the print together with the exterior nebulosity, but I have done no manipulating of this sort. The sole process used has been to make a contact positive print on glass from the original negative, and a second negative on glass by a contact print from the positive. A silver print on paper was made in the usual way from the second negative, and the engraving was made by the half-tone process from the silver print. Both negatives and the positive were developed with a strong hydrochinon developer, giving great contrast. The original negative was made on an 8 x 10 Cramer crown plate, and the positive and second negative on Seed transparency plates. The reproduction is made on the scale of the original.

Since 1899 I have been so occupied with other duties that I have been able to give very little time to long exposure photographs.

It is therefore with a great deal of pleasure that I see before me this summer the prospect of a little leisure, and above all of the opportunity to experiment in celestial photography at a high altitude. Through the courtesy of the officials of the Great Northern Railroad, and other friends who have been interested

in our work, Professor Payne and I will be enabled to take our photographic outfit to the mountains in western Montana, and to determine by experiment whether the atmosphere at an altitude of about one mile in that region is better suited to the problem of photographing the faint nebulous areas and the Milky Way, than is the Minnesota air at home at an altitude of about 950 feet.

We plan to start about the last of June and to utilize in our experiments the moonless nights of July and August; and it is our hope to obtain successful photographs of a few of Herschel's nebulous regions as well as of the Milky Way.

THE SATURNIAN SYSTEM.

D. G. PARKER.

FOR POPULAR ASTRONOMY.

Up to 1781 when Sir Wm. Herschel discovered Uranus, the planet Saturn was supposed to mark the outer boundary of our solar system. Although apparently known to the ancients from the morning dawn of history, nothing remarkable was suspected until 1610 when Galileo addressed his quaint message to the Duke of Tuscany, in which he said: "When I view Saturn, it seems tricorps;" the explanation being that his telescope, then just completed, was of insufficient magnifying power to give more than an indefinite right and left glimpse of the great appendages, and these he declared to be "Companions helping old Saturn on his way."

That the planet was known long before even the rudiments of astronomy became a scientific study, is demonstrated by the fact that the earliest mythological conceptions were woven around it, while in naming the days which make up the weekly calendar, Saturn was honored in the suggestive nomenclature.

Of all the major planets known, he is the lightest in density; so light in fact that no object of animal life known to us, could possibly survive in the elements constituting the atmosphere or liquids of that remarkable body.

The majesty of physical and universal law, is happily illustrated by his movements: A body 73,000 miles in diameter, more than nine times that of the Earth, separated from the Sun by the inconceivable distance of nearly 900 millions of miles, flying through space at the startling velocity of six miles per sec-

ond, yet held by a firm grasp to a well defined track more than fifty-five hundred millions of miles in length, and making periodic rounds with critical exactness, "Not an inch out of space, nor a second out of time."

When we consider the magnitude of bulk; its extremely light density, and the rapid revolution upon its axis, (over 22,000 miles per hour) there can be no surprise that the equatorial line exceeds that of the polar, so greatly—(7000 miles). A swiftly turning grindstone may illustrate. Gathering the fluid in its rapid motion, it is thrown off from the central line. So, every inch of extra padding over the equatorial belt of a planet has been irresistibly drawn from the polar extremities by the balancing of gravitating and centrifugal forces.

On each side, and parallel with the equator, may be dimly seen, dark belt markings which change their forms from time to time, and these are supposed to be clouds floating in an atmosphere of great depth. This presumption not only satisfies the observation best, but carries out the analogy with what is more clearly seen upon Jupiter, and what we know exists upon the Earth. The atmosphere of the torrid zone, being warmer and therefore lighter, than that of the polar, this latter is constantly rushing in from both sides to equalize. Meeting, they roll back upon themselves forming the parallel belts as seen.

This is confessedly somewhat speculative, and not knowing thermal, or other conditions as we do here, our speculations are loaded with many elements of uncertainty. The fact is, we are separated by a wide and impassable gulf. It takes large and clear glasses to read a poster 900 million miles away.

Assuming the Sun to be the principal source of heat, it has been estimated that the atmosphere of Saturn is charged with a temperature 90 degrees lower than ours. Doubtless we may never know all the conditions effecting temperature upon the various planets, and we reason therefore from analogy. Our mathematical presumption is, that the reflective power of the Sun, is in proportion to distance. We may be so far removed from the largest body, that it reflects only a point of light, and is finally lost entirely from view. The heat diminishes as the light fades away. With this thought in mind, conclusions may be drawn by noting the comparative size of the Sun as seen from the Earth, and by the Saturnian astronomer. (About 10 to 1).

The reflective surface of Saturn, must include his rings; hence it is apparent that between degrees of ring shading, and the varying distance of the planet from the Earth (741 and 1122

million miles, extremes) there is a marked difference in his brilliancy from time to time.

On the La Place theory of building up in successive order, by nebular process, it is difficult to give a reason why this body should be so much lighter in density than Jupiter; being so much smaller, and separated from the Sun, presumptively, so much earlier. It is a question whether the whole theory may not break down under a close analysis of the varying conditions of these two planets.

Ancient mythology filled Earth and sky with imaginary deities. In this drama of the gods, Saturn was ushered in as the youngest son of Uranus and Gaia. He was afterwards banished by an edict of Jupiter, the chief god, and fled to Latium where he was cordially received by Janus, and invested with equal power on the throne of that sovereignty. His reign was so popular that it became known as "The Golden Age," and the Saturnalia festival given to his honor in December of each year, is an occasion celebrated with great pomp and given to almost unbridled indulgences.

It is doubtless known only to few, other than students in astronomy, that

A Comet Family

of indefinite numbers make periodic excursions between, and around this planet and the Sun. How these come to be drawn in from the outer depths of ethereal spaces and made a part of our solar system, is a subject highly speculative and belongs to a separate paper.

The ponderous Jupiter, midway between Saturn and the Sun, not infrequently contests the allegiance of these excursionists, and notable instances of capture are recorded.

The most remarkable fact concerning this planet is the marvelous number of appendages which go to make up his system. Nature was more than prodigal in his ornamentation. So far as we know, it is the only body in the universe of stars, ring encircled.

Multiplicity of Moons.

No other discovered planet is accompanied by more than five moons, while this one is known to have eight, with strong presumptions of three others, yet undiscovered. If then, the La Place doctrine is to be accepted, this planet, after having himself emerged from the Sun, then in turn abandoned no less than 14 nebulous rings. Why such prodigality confined to this one, is a question which will probably never be satisfactorily answered.

With the exception of the most distant satellite, they are all substantially in plane with each other, and with the rings. These rings had been under investigation 45 years before a moon was detected, even then only one, and it was 193 years later, before the last of the eight was gathered in.

The honor of these discoveries is divided between Huyghens and Herschel of England, Cassini of Italy, and Bond of Cambridge, Mass., and it would seem that, "The end is not yet," for it is a fair mathematical conclusion that at least three other satellites remain undiscovered; that is to say, under a presumptive law suggesting planetary distances, the wide space between No.s 5 and 6, calls for one, while it requires two, if not three, to complete the spacing between 7 and 8.

If we call these Saturnian satellites, companions, it would seem to be a misnomer, for none of them are within hailing distance or on speaking terms. No. 1 is about 117,000 miles from the planet while No. 8 stretches away nearly two and one-half millions of miles. Nevertheless, however distant and formal, they are not without respectful recognition, for every transit causes perturbating sensitiveness, and the resistless power of attraction is felt in proportion to size and distance.

Mythical Fancies.

I have spoken of the fanciful inagery with which the ancients clothed nearly every material thing in Earth and sky, and so deeply impressive was this, that the learned masters of modern times have borrowed largely to embellish their own works. In selecting names for these satellites, they were deeply colored with these fascinating myths.

No. 1, *Mimas*, is a Trojan, having contemporaneous birth with Paris.

Enceladus, the next, seems to be an exception in these mythical embellishments.

Tethys is very romantic. As the wife of Oceanus, god of Ocean currents, she became mother of all the chief rivers in the universe, as also the oceanides or sea nymphs.

Dione was one of the wives of Zeus, the superintending god.

Rhea was one of the six Titan daughters born to Uranus. She was espoused to Saturn and became the mother of Vesta, Ceres, Juno and Pluto.

Titan was the oldest son of Uranus. A conflict with his younger brother, Saturn, arose as to their respective right of sovereignty over gods and men, which was finally settled by Jupiter in favor of the latter.

I pause here to note that the estimated diameter of this moon, (3500 miles) which Professor Barnard challenges, gives it the dignity of a world considerably larger than the planet Mercury.

Hyperion is known as the god of day, and father of Sun and Moon. Notwithstanding this mythical exaltation, he is doubtless the smallest of the celebrated group.

Japetus was the fifth son of Uranus and father of Atlas and Prometheus. He swings upon the outer boundary, and has excited the wonder of astronomers in the variability of his brilliancy, as well as the remarkable inclination in the plane of his orbit.

The Rings of Saturn.

No object in the heavens has awakened more interest or excited greater discussion than the rings of this planet. Saturn is the only known body arched with such an appendix or encircled by a brilliancy so remarkable. Of the many theories advanced as to their composition, that of Professor Maxwell (meteoric) has become most popular and will doubtless stand the test of analysis.

Why have not these rings condensed into moons? This is answered by the late Professor Roach who showed that a body brought within a given distance of its primary's radii, would be torn into fragments between the gravitating and centrifugal forces. These rings are found to be within the destructive limit.

Advocates of the nebular hypothesis point to these flaming arches as a practical demonstration of their theory, which it is not the purpose of this article to affirm nor deny; but there are some interesting speculations as to possible changes going on, which it is not out of place to note.

Observations by the leading astronomers from 1657 to 1851, uniformly concurred in raising a suspicion that gravity is overcoming the centrifugal force, and that it is only a question of time when the whole will be precipitated upon the central body. They even gave the rate of approach, and the approximate time of the great catastrophe. I need not say that the distinguished scientists of our times, do not share this alarm.

But if true, how terrible will be the bombardment! The steady approach of these flying missiles will only increase their velocity until finally grazing the surface they will ricochet through several revolutions until the centrifugal force is exhausted. This is succeeded by the next zone, and still the next, through successive centuries. Can one imagine the fury of such a storm or the violence of such an impact?

Wait a moment. We will not waste our sympathy upon the poor denizens of that unfortunate world. There will be no such calamity. I have been reasoning as if the planet is without atmosphere. Let us take another view. From analogy, as also the cloudy belts witnessed, we may assume that Saturn has an atmosphere, upon entering which, the flight of these meteors will be immediately arrested, with the result of a momentary flash, and then they will be lost in utter extinguishment. What has become of them? They are totally consumed by atmospheric friction.

It is needless to say that meteors are not confined to the rings of Saturn. The celestial spaces are packed, so to speak, with these strange wanderers. It is estimated by high authority, that more than fifteen millions are encountered by our planet daily, and yet we rest quietly unconscious of danger. Such is the protecting shield of atmosphere.

Shall we speak of scenery? We instinctively enjoy the beauties of nature as revealed in our own surroundings, but what shall be said of scenery a thousand times more gorgeous.

For a moment allow ourselves to be transported to the planet Saturn. In one of the zones corresponding to our temperate one, we stand appalled at the startling grandeur, above, beneath, around. We are dazzled by the electrical splendor.

Eleven, possibly twelve moons, as varied in size as they are in distance, chase each other in quick succession across the sky, while within the orbit of these stands a flaming arch nearly 50,000 miles high, covering the whole planet with a reflective brilliancy which no pen can picture nor tongue describe.

PORT ARTHUR, Texas.

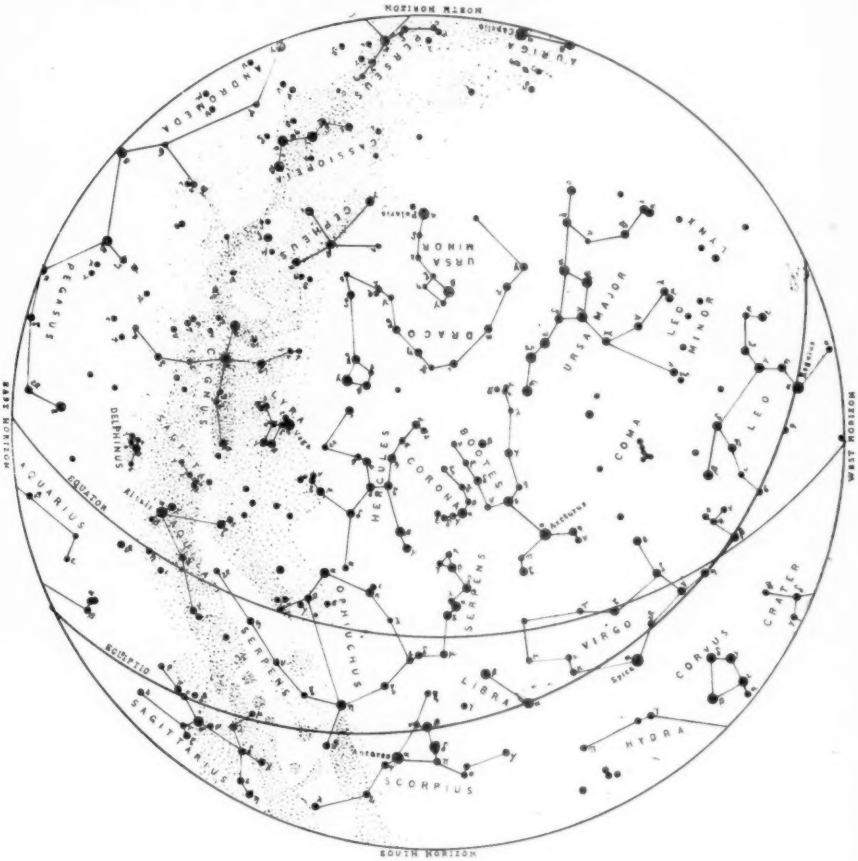
PLANET NOTES FOR JULY AND AUGUST.

H. C. WILSON.

Mercury will be at superior conjunction July 9 and so will not be visible during this month, but about the middle of August it will become visible in the evening, reaching greatest eastern elongation August 19. Mercury will be in conjunction with Mars on July 2, with Neptune July 4 and with Venus July 10, but at that time all four planets will be hidden in the glare of the Sun.

Venus will be at superior conjunction July 8 at 1 A. M., Central Standard time, and will be hidden in the rays of the Sun during the greater part of July. In August she will be evening star, but will not be far enough out from the solar glare to be easily observed.

Mars will be morning star during these months, and at a high northern declination, but not far enough from the Sun for satisfactory observations. Mars and Neptune will be in conjunction on the morning of July 9.



THE CONSTELLATIONS AT 9 P. M. JULY 1, 1904.

Jupiter will be at quadrature, 90° west from the Sun, July 21, and may be observed in the morning hours during the summer months. He will be at the stationary point in his apparent path on Aug. 20.

Saturn is in as good position as he can have this year, during these two months. He will be at opposition Aug. 10, and is to be seen any clear morning now in the constellation Capricornus. The rings are plainly visible, and when the seeing is good the details of structure can be made out. Three or four satellites are always visible and sometimes five or six may be seen with a small telescope.

Uranus is also in good position for study, except for the fact of his low altitude. He may be easily found with a small telescope, close to the ecliptic in the western part of the constellation Sagittarius.

Neptune being just past conjunction will not be in position for observation during these months.

The Moon.

1904	Phases.		Rises. (Central Standard Time at Northfield. Local Time 13m less.) h m		Sets. h m	
July	4-5	Last Quarter	11	39 P. M.	12	13 P. M.
	12	New Moon	4	13 A. M.	7	19 "
	19	First Quarter	12	32 P. M.	11	49 "
	26-27	Full Moon	7	9 "	5	13 A. M.
Aug.	3- 4	Last Quarter	11	6 "	1	02 P. M.
	11	New Moon	5	17 A. M.	7	27 "
	17	First Quarter	12	37 P. M.	11	04 "
	25-26	Full Moon	6	50 "	6	00 A. M.

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle f'm N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle f'm N pt. °	Duration. h m
July 1	B.A.C. 7697	6.8	10 01	102	11 03	231	1 02
21	η Libræ	5.5	6 39	94	8 2	302	1 23
22	24 Scorpii	5.2	8 56	52	9 56	326	1 00
25	ρ^2 Sagittarii	6.1	8 25	78	9 50	277	1 25
25	B.A.C. 6658	7.0	13 12	151	13 33	182	0 21
Aug. 5	48 Tauri	6.4	12 11	92	13 02	241	0 51
5	γ Tauri	3.9	13 56	93	14 55	236	0 59
5	70 Tauri	6.3	17 09	112	18 14	217	1 05
20	Υ Sagittarii	Var.	12 27	71	13 32	274	1 05
23	W.B. xx, 1293	6.0	15 19	114	16 06	209	0 47
24	λ Capricorni	5.4	15 33	32	16 27	286	0 54

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered by	Discovered at	Local M. T.	R. A. h m	R. A. h m	Decl. ° ′	Mag.
1902 NU	Wolf	Heidelberg	1902 Mar. 10	13 54.9	12 52.1	— 6 17	13
1894 NV	"	"	1904 Apr. 11	13 55.9	13 55.5	+ 0 32	12.6
1904 NW	"	"	12	11 16.9	13 55.4	— 2 06	12.6
1904 NX	"	"	16	10 25.9	13 08.3	+ 28 49	13.0
1904 NY	"	"	20	11 11.4	13 53.0	+ 18 23	9.2
1904 NZ	Dugan	"	19	10 00.0	14 12.1	— 7 50	13.2
1904 OA	"	"	19	13 21.0	13 57.6	— 7 17	13.0
1904 OB	Wolf	"	21	12 56.4	14 47.0	— 0 41	13.2

Comet *a* 1904 (Brooks.)—The new comet is still visible with a telescope but is slowly growing fainter. It is following closely the approximate course indicated by continuing the line drawn on our diagram in the last number of POPULAR ASTRONOMY. Another set of elliptic elements has been computed by Messrs. Ralph H. Curtiss and Sebastian Albrecht, using Professor Leuschner's "Short Method." This time the eccentricity comes out 0.575 and the period 15.14 years instead of 3.02 years. Later observations indicate that with a longer arc of the orbit the eccentricity and the period will be greater. The fact that the inclination of the orbit is 125° would *a priori* suggest that the comet is not one of short period, for no known periodic comet has a retrograde motion around the Sun.

Professor Leuschner makes the following statement concerning the use of his method (Lick Obs. Bulletin No. 55): "The advisability of determining an orbit from a short arc without hypothesis as to the eccentricity might be questioned, were it not for the fact that in applying the 'Short Method' the aim is to determine as rapidly as possible a finding ephemeris which accurately represents the given observations, the computation of the elements being incidental to conform to established custom. The fact that such an ephemeris, as far as comets are concerned, can thus be derived more conveniently than by means of a preliminary parabola is sufficient justification for departing from the old method. In many cases the periodic character of an orbit is readily revealed from a short arc."

ELEMENTS OF COMET *a* 1904.

Computers: Curtiss and Albrecht.

Epoch 1904 April 22.77234

$M_0 = 4^\circ\ 16'\ 58''$
$\omega = 47\ 39\ 53$
$\Omega = 274\ 10\ 26$ 1904
$i = 115\ 22\ 32$
$e = 0.57512$
$\log a = 0.78661$
$\mu = 234''.47$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1904	True α h m s	True δ ° ′	log Δ	Brightness.
May 3.5	16 00 29	+ 53 24.8	0.33644	0.91
7.5	15 43 07	54 57.1		
11.5	15 24 50	56 10.9	0.34822	0.85
15.5	15 06 06	57 05.7		
19.5	14 47 22	57 41.9	0.36419	0.78
23.5	14 29 09	58 00.6		
27.5	14 11 46	58 03.8	0.38306	0.71
31.5	13 55 33	57 55.6		
June 4.5	13 40 51	57 31.9	0.40359	0.63
8.5	13 27 35	57 01.1		
12.5	13 15 52	56 24 2	0.42474	0.56

Parabolic elements have been calculated by several computers and seem to represent the observations well. The latest, which have come to hand as we are about to go to press, are by Mr. Everett I. Yowell, computer at the U. S. Naval Observatory.

The accompanying diagram, prepared by the Junior class in Practical Astronomy at Carleton College shows well the relation of the comet's orbit to those of the planets. At perihelion, about the first of March, the comet was as far from the Sun as is the average asteroid; it was nearest the Earth in April and is now receding from us. It must in reality be quite a large comet, appearing

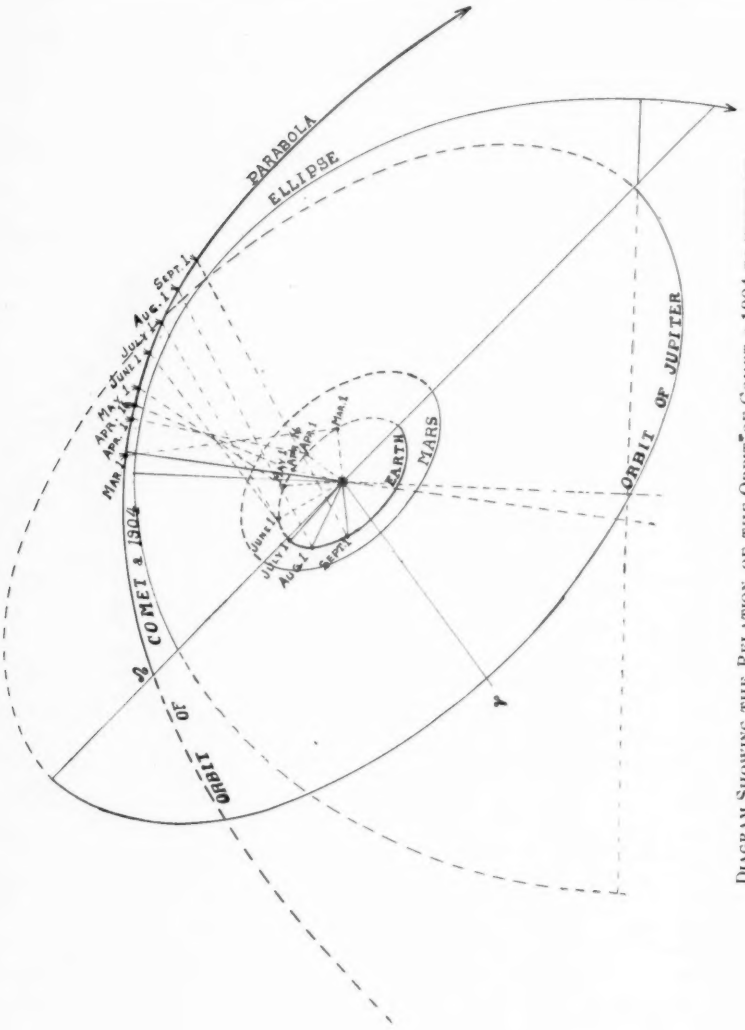


Diagram Showing the Relation of the Orbit of Comet *a* 1904 to those of the Planets Earth, Mars and Jupiter.

small to us because of its great distance. The half ellipse shown is drawn from the elements of Curtiss and Albrecht and the parabola from Yowell's elements.

Elements and Ephemeris of Comet *a* 1904 (Brooks.)—The following parabolic elements were obtained from normal places formed by combining observations made at the U. S. Naval Observatory on April 17 and 18, 22 and 23, 30 and May 1:

$$T = 1904 \text{ March } 5.7688 \text{ G. M. T.}$$
$$\pi = 328^\circ\ 43'\ 47''.6$$
$$\Omega = 275\ \ 41\ \ 22\ .8 \quad 1904.0$$
$$i = 125\ \ \ 6\ \ 17\ .4$$
$$\log q = 0.431988$$

HELIOCENTRIC COORDINATES.

$$x = r\,[9.764001] \sin (223^\circ\ 12'\ 40''.0 + v).$$
$$y = r\,[9.994756] \sin (300\ \ 33\ \ 10\ .4 + v).$$
$$z = r\,[9.918342] \sin (24\ \ 29\ \ 22\ .0 + v).$$

EPHEMERIS.

G. M. T.		α h	α m	α s	δ °	δ ′	δ ″	log Δ	Brightness.
June	1.5	13	52	13.3	+ 57	59	1	0.41797	0.67
	2.5		48	28.5		54	27	0.42060	0.66
	3.5		44	49.1		49	17	0.42324	0.65
	4.5		41	15.2		43	31	0.42560	0.64
	5.5		37	46.8		37	12	0.42855	0.64
	6.5		34	24.0		30	22	0.43122	0.63
	7.5		31	6.9		23	3	0.43389	0.62
	8.5		27	55.3		15	16	0.43657	0.61
	9.5		24	49.3	57	7	4	0.43926	0.60
	10.5		21	49.0	56	58	27	0.44194	0.59
	11.5		18	54.2		49	29	0.44462	0.58
	12.5		16	4.9		40	11	0.44730	0.57
	13.5		13	21.1		30	34	0.44998	0.56
	14.5		10	42.6		20	40	0.45266	0.56
	15.5		8	9.4		10	31	0.45532	0.55
	16.5		5	41.5	56	0	7	0.45798	0.54
	17.5		3	18.6	55	49	30	0.46064	0.53
	18.5	13	1	0.8		38	42	0.46328	0.52
	19.5	12	58	47.9		27	43	0.46591	0.52
	20.5		56	39.8		16	36	0.46753	0.51
	21.5		54	36.4	55	5	20	0.47014	0.51
	22.5		52	37.6	54	53	57	0.47374	0.50
	23.5		50	43.2		42	28	0.47632	0.49
	24.5		48	53.2		30	55	3.47889	0.48
	25.5		47	7.4		19	17	0.48144	0.48
	26.5		45	25.8	54	7	35	0.48397	0.47
	27.5		43	48.2	53	55	51	0.48649	0.46
	28.5		42	14.5		44	5	0.48899	0.46
	29.5		40	44.6		32	18	0.49147	0.45
	30.5		39	18.3	53	20	30	0.49394	0.45
July	4.5	12	34	8.3	+ 52	33	21	0.50358	0.42

The brightness at the date of discovery is adopted as the unit. Comparison with an observation made here May 16 gives as corrections to the ephemeris: $\Delta\alpha = -3^s$, $\Delta\delta = +16''$. EVERETT I. YOWELL.

[Communicated by Rear-Admiral C. M. Chester, U. S. N., Superintendent].

PHENOMENA OF JUPITER'S SATELLITES.

[Central Standard Time].

July	2	12	31	A. M.	I Sh. In.	Aug.	8	12	06 A. M. II Sh. Eg.
		1	52	"	I Tr. In.			12	21 " II Tr. In.
		2	46	"	I Sh. Eg.			2	47 " II Tr. Eg.
		4	5	"	I Tr. Eg.		9	1	41 " I Ec. Dis.
	3	1	14	"	I Oc. Re.			3	49 " III Sh. In.
	7	12	23	"	II Sh. Eg.			9	45 P. M. II Oc. Re.
		12	38	"	II Tr. In.			10	58 " I Sh. In.
		3	06	"	II Tr. Eg.		10	12	19 A. M. I Tr. In.
	8	3	21	"	III Oc. Dis.			1	12 " I Sh. Eg.
	9	2	26	"	I Sh. In.			2	31 " I Tr. Eg.
		3	48	"	I Tr. In.			11	39 P. M. I Oc. Re.
	11	12	30	"	I Tr. Eg.		12	11	21 " III Oc. Dis.
	14	12	27	"	II Sh. In.		13	12	54 A. M. III Oc. Re.
		2	59	"	II Sh. Eg.		15	12	12 " II Sh. In.
		3	17	"	II Tr. In.			2	43 " II Sh. Eg.
	15	1	43	"	III Ec. Dis.			2	52 " II Tr. In.
		3	51	"	III Ec. Re.		16	3	35 " I Ec. Dis.
	16	12	51	"	II Oc. Re.			9	41 P. M. II Ec. Re.
	17	1	30	"	I Ec. Re.			9	47 " II Oc. Dis.
	18	12	13	"	I Tr. In.		17	12	12 A. M. II Oc. Re.
		1	2	"	I Sh. Eg.			12	52 " I Sh. In.
		2	25	"	I Tr. Eg.			2	09 " I Tr. In.
		11	30	P. M.	III Tr. Eg.			3	05 " I Sh. Eg.
		11	33	"	I Oc. Re.			10	03 P. M. I Ec. Dis.
	21	3	03	A. M.	II Sh. In.		18	9	34 " I Sh. Eg.
	23	12	39	"	II Ec. Re.			10	48 " I Tr. Eg.
		12	59	"	II Oc. Dis.		19	9	50 " III Ec. Dis.
		3	26	"	II Oc. Re.			11	50 " III Ec. Re.
	24	3	24	"	I Ec. Dis.		20	3	07 A. M. III Oc. Dis.
	25	12	42	"	I Sh. In.		22	2	49 " II Sh. In.
		2	06	"	I Tr. In.		23	9	50 P. M. II Ec. Dis.
		2	56	"	I Sh. Eg.		24	2	37 A. M. II Oc. Re.
	26	1	27	"	I Oc. Re.			2	46 " I Sh. In.
		1	42	"	III Tr. In.			3	58 " I Tr. In.
		3	27	"	III Tr. Eg.			11	58 P. M. I Ec. Dis.
		10	47	P. M.	I Tr. Eg.		25	3	18 A. M. I Oc. Re.
	28	12	48	A. M.	II Ec. Dis.			8	58 P. M. II Tr. Eg.
		3	14	"	II Ec. Re.			9	14 " I Sh. In.
		3	33	"	II Oc. Dis.			10	25 " I Tr. In.
Aug.	1	12	15	"	II Tr. Eg.			11	28 " I Sh. Eg.
		2	35	"	I Sh. In.		26	12	37 A. M. I Tr. Eg.
		11	47	P. M.	I Ec. Dis.			9	46 P. M. I Oc. Re.
		11	48	"	III Sh. In.		27	1	51 A. M. III Ec. Dis.
	2	2	05	A. M.	III Sh. Eg.			3	50 " III Ec. Re.
		10	27	P. M.	I Tr. In.		30	8	44 P. M. III Tr. In.
		11	18	"	I Sh. Eg.			10	08 " III Tr. Eg.
	3	12	39	A. M.	I Tr. Eg.		31	12	25 A. M. II Ec. Dis.
	6	3	23	"	II Ec. Dis.				

VARIABLE STARS.

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
July	1- 5	14	July	22-28	17	Aug.	5-12	19	Aug.	21-28	21
	6-13	15		28-35	18		13-20	20		29-36	22
	14-21	16									

Minima of Variable Stars of the Algol Type.

[Alternate minima only are given for the Algol variables, this month].

U Cephei.		RR Velorum.		U Coronae.		Z Herculis.		RX Herculis.	
d	h	d	h	d	h	d	h	d	h
July 5	18	July 2	13	July 3	2	July 1	21	Aug. 16	16
10	17	6	6	10	0	3	18	18	11
15	17	9	23	16	22	9	21	20	6
20	17	13	16	23	20	11	18	22	0
25	16	17	9	30	17	17	20	23	19
30	16	21	2	Aug. 6	15	19	17	25	14
Aug. 4	16	24	19	13	13	25	20	27	8
9	15	28	12	20	10	27	17	29	3
14	15	Aug. 1	5	27	8	Aug. 2	20	30	22
19	15	4	22			4	16		
24	14	8	15	R Aræ.		10	19	RV Lyræ.	
29	14	12	8	July 5	1	12	16	July 3	21
Z Persei.		16	1	13	21	18	19	11	2
July 4	21	19	18	22	17	20	16	18	7
11	0	23	11	31	14	26	18	25	11
17	2	27	4	Aug. 9	10	28	15	Aug. 1	16
23	5	30	21	18	7	RS Sagittarii.		8	21
29	8	Z Draconis.		27	3	July 1	8	16	1
Aug. 4	10	July 1	9	U Ophiuchi.		6	4	23	6
10	13	4	3	July 1	1	11	0	25	11
16	16	6	19	2	17	15	20	U Sagittæ.	
22	19	9	12	4	9	20	16	July 1	22
28	21	12	5	6	1	25	12	8	16
Algol.		14	22	7	18	30	8	15	10
July 2	11	17	16	9	10	Aug. 4	4	22	5
8	5	20	9	11	2	9	0	28	23
13	22	23	2	12	18	13	20	Aug. 4	17
19	16	25	19	14	11	18	16	11	11
25	10	28	12	16	3	23	12	18	6
31	3	31	5	17	19	28	8	25	0
Aug. 5	21	Aug. 2	22	19	12	RX Herculis.		31	18
11	14	5	15	21	4	July 1	11	SY Cygni.	
17	8	8	9	22	20	3	5	July 6	19
23	2	11	2	24	12	5	0	18	19
28	19	13	19	26	5	6	19	30	19
λ Tauri.		16	12	27	21	8	13	Aug. 11	20
July 2	10	19	5	29	13	10	8	23	20
10	8	21	23	31	5	12	3	SW Cygni.	
18	5	24	16	Aug. 1	22	13	21	July 4	12
26	3	27	9	3	14	15	16	13	16
Aug. 3	1	30	2	5	6	17	11	22	19
10	23	δ Librae.		6	22	19	5	31	23
18	21	June 1	22	8	15	21	0	Aug. 10	2
26	18	6	14	10	7	22	19	19	6
S Velorum.		11	6	11	23	24	13	28	9
July 2	18	15	21	13	15	26	8	UW Cygni.	
14	15	20	13	15	8	28	3	July 1	18
26	12	25	5	17	0	29	21	8	16
Aug. 7	9	29	20	18	16	31	15	15	13
19	5	Aug. 3	12	20	8	Aug. 2	11	22	11
31	2	8	4	22	1	4	6	29	9
W. Urs. Maj.		12	20	23	17	6	0	Aug. 5	6
Period 4h 0m.1		17	11	25	9	7	19	12	4
July 1-31 12h		22	3	27	1	9	14	19	2
Aug. 1-31 13		26	19	28	18	11	8	25	23
		31	10	30	10	13	3		
						14	22		

Minima of Variable Stars of the Algol Type.—Continued.

W Delphini.

	d	h
July	2	17
	12	7
	21	22
	31	13
Aug.	10	3
	19	18
	29	9

VV Cygni.

	d	h
July	1	12
	4	11
	7	10

VV Cygni.

	d	h
July	10	9
	13	8
	16	7
	19	6
	22	4
	25	3
	28	2
	31	1
Aug.	3	0
	5	23
	8	22
	11	21

VV Cygni.

	d	h
Aug.	14	20
	17	19
	20	17
	23	16
	26	15
	29	14

VW Cygni.

	d	h
July	4	1
	23	22
Aug.	9	18
	26	15

Y Cygni.

	d	h
July	3	16
	5	1
	9	16
	11	1
	15	15
	17	0
	21	15
	23	0
	27	15
	29	0
Aug.	2	15
	4	0

Y Cygni.

	d	h
Aug.	8	15
	10	0
	14	15
	16	0
	20	14
	21	23
	26	14
	27	23

UZ Cygni.

	d	h
July	20	19
Aug.	21	3

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.59$. The minimum occurs $1^h\ 55^m$ before the maximum.

	d	h
July	2	2
	4	8
	6	14
	8	20
	11	2
	13	7
	15	13
July	17	19
	20	1
	22	7
	24	13
	26	18
	29	0
	31	6
Aug.	2	12
	4	18
	7	0
	9	5
	11	11
	13	17
	15	23
Aug.	18	5
	20	11
	22	16
	24	24
	27	4
	29	10

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h
July	1	8
	3	9
	5	10
	7	11
	9	12
	11	13
	13	14
	15	16
July	17	17
	19	18
	21	19
	23	20
	25	21
	27	22
	29	23
Aug.	1	0
	3	1
	5	3
	7	4
	9	5
	10	6
	12	7
	14	8
Aug.	16	9
	18	10
	20	11
	22	12
	24	13
	26	14
	28	15
	30	16

RX (10.1903) Lyræ.—In A. N. 3943 Mr. W. Stratanow of Tachkent, Russia, gives the results of an examination of the impression of this star on 122 plates in the years 1895-1900. He finds a decided maximum indicated in July 1896 and another in October 1897. By combining the maximum on July 15, 1896, with that on April 21, 1903, he finds for the period 247 days. The magnitude at maximum is 12, while that at minimum is 16 or below.

Variable 86.1903 Tucanæ.—This star is reported by Dr. David Gill to be a long period variable, from 8.0 magnitude to invisible. Its position according to the CPD (Cape Photographic Durchmusterung) is

1875.0 R. A. $22^h\ 32^m\ 17^s.9$; Decl. $-62^\circ\ 12'.2$.

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.			Minimum.		Maximum.	
	d	h	d	h		d	h	d	h
S Normae	July 1	11	July 5	21	V Carinae	July 16	7	July 18	11
T Velorum	1	16	3	1	T Vulpeculae	16	17	18	2
δ Cephei	1	20	3	5	X Sagittarii	16	21	19	18
U Vulpeculae	2	0	4	3	U Sagittarii	17	2	20	1
V Velorum	2	3	3	2	U Aquilae	17	5	19	9
X Sagittarii	2	20	5	17	Y Sagittarii	17	15	19	10
V Carinae	2	23	5	3	RV Scorpii	17	15	19	1
U Aquilae	3	5	5	9	κ Pavonis	17	20	21	15
S Triang. Austr.	8	7	5	9	δ Cephei	17	23	19	8
U Sagittarii	3	14	6	13	R Crucis	18	6	19	15
Y Ophiuchi	4	7	10	12	U Vulpeculae	18	10	20	13
SU Cygni	4	15	5	23	S Crucis	18	23	20	11
S Crucis	4	22	6	10	β Lyræ	19	10	22	12
S Sagittæ	5	10	8	20	V Velorum	19	15	20	14
S Muscae	5	10	8	21	SU Cygni	20	0	21	8
RV Scorpii	5	12	6	22	T Velorum	20	5	21	14
Y Sagittarii	6	2	7	21	T Crucis	20	8	22	9
T Velorum	6	7	7	16	S Normae	21	0	25	10
β Lyræ	6	12	9	14	T Vulpeculae	21	3	22	12
V Velorum	6	12	7	11	V Centauri	21	5	22	16
R Crucis	6	15	8	0	Y Ophiuchi	21	10	27	15
W Sagittarii	6	15	9	15	η Aquilae	21	18	24	3
T Crucis	6	21	8	22	W Sagittarii	21	20	24	20
δ Cephei	7	5	8	14	S Sagittae	22	5	25	15
η Aquilæ	7	10	9	19	S Triang. Austr.	22	7	24	9
T Vulpeculae	7	20	9	5	TX Cygni	22	21	28	0
TX Cygni	8	4	13	7	V Carinae	23	0	25	4
SU Cygni	8	11	9	19	δ Cephei	23	7	24	16
κ Pavonis	8	18	12	13	Y Sagittarii	23	9	25	4
S Crucis	9	14	11	2	RV Scorpii	23	16	25	2
V Carinae	9	15	11	19	U Sagittarii	23	20	26	19
S Trianguli Austr.	9	15	11	17	SU Cygni	23	20	25	4
X Sagittarii	9	20	12	17	X Sagittarii	23	21	26	18
U Vulpeculae	9	23	12	2	V Velorum	24	0	24	23
U Aquilae	10	5	12	9	R Crucis	24	2	25	11
V Centauri	10	6	11	17	U Aquilae	24	6	26	10
U Sagittarii	10	8	13	7	S Crucis	24	16	26	4
W Virginis	10	9	18	14	S Muscae	24	18	28	5
V Velorum	10	21	11	20	T Velorum	24	21	26	6
T Velorum	10	22	12	7	T Vulpeculae	25	14	26	23
X Cygni	11	0	17	5	β Lyrae	25	21	29	0
S Normae	11	5	15	15	U Vulpeculae	25	23	28	2
RV Scorpii	11	13	12	23	V Centauri	26	17	28	4
Y Sagittarii	11	20	13	15	κ Pavonis	26	22	30	17
T Vulpeculae	12	6	13	15	T Crucis	27	3	29	4
SU Cygni	12	7	13	15	X Cygni	27	9	33	14
R Crucis	12	11	13	20	W Virginis	27	16	35	21
δ Cephei	12	14	13	23	SU Cygni	27	17	29	1
β Lyræ	12	23	16	6	S Crucis	28	8	29	20
T Crucis	13	15	15	16	V Velorum	28	9	29	8
S Sagittæ	13	20	17	6	S Triang. Austr.	28	15	30	17
T Monocerotis	13	21	22	7	δ Cephei	28	18	30	3
W Sagittarii	14	5	17	5	η Aquilae	28	22	31	7
S Crucis	14	7	15	19	Y Sagittarii	29	4	30	23
η Aquilae	14	14	16	23	W Sagittarii	29	10	32	10
S Muscae	15	2	18	13	T Velorum	29	12	30	21
V Velorum	15	6	16	5	V Carinae	29	16	31	20
T Velorum	15	14	16	23	RV Scorpii	29	18	31	4
V Centauri	15	18	17	5	R Crucis	29	22	31	7
S Triang. Austr.	15	23	18	1	T Vulpeculae	30	0	31	9
SU Cygni	16	3	17	11	U Sagittarii	30	14	Aug. 2	13

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum.		Maximum.			Minimum.		Maximum.	
	d	h	d	h		d	h	d	h
S Sagittae	July 30	14	Aug. 3	0	W Virginis	Aug. 13	22	Aug. 22	3
S Normae	30	18	5	4	κ Pavonis	14	3	17	22
X Sagittarii	30	21	2	18	β Lyrae	14	6	17	8
U Aquilae	31	6	2	10	U Aquilae	14	7	16	11
SU Cygni	31	13	1	21	ζ Geminorum	14	14	19	14
V Centauri	Aug. 1	5	2	16	V Velorum	14	20	15	19
β Lyrae	1	8	4	10	Y Sagittarii	15	11	17	6
V Velorum	1	18	2	17	SU Cygni	15	22	17	6
S Crucis	2	1	3	13	W Geminorum	16	1	18	16
T Crucis	2	20	4	21	S Crucis	16	3	17	15
U Vulpeculae	2	23	5	2	T Crucis	16	7	18	8
δ Cephei	3	1	4	10	S Sagittae	16	8	19	18
T Velorum	3	3	4	12	R Crucis	16	9	17	18
S Muscae	3	10	6	21	S Triang. Austr.	16	14	18	16
T Vulpeculae	3	11	4	20	T Vulpeculae	16	18	18	3
Y Sagittarii	3	22	5	17	RV Scorpii	16	22	18	8
S Triang. Austr.	3	23	6	1	T Velorum	17	1	18	10
SU Cygni	4	9	5	17	V Centauri	17	17	19	4
R Crucis	4	18	6	3	V Carinae	18	19	20	23
RV Scorpii	4	19	6	5	U Vulpeculae	18	22	21	1
κ Pavonis	5	1	8	20	δ Cephei	19	4	20	13
η Aquilae	5	3	7	12	V Velorum	19	5	20	4
V Carinae	5	10	7	14	S Normae	19	6	23	16
W Sagittarii	6	0	9	0	η Aquilae	19	11	21	20
V Velorum	6	2	7	1	SU Cygni	19	19	21	3
U Sagittarii	6	8	9	7	U Sagittarii	19	20	22	19
TX Cygni	6	15	11	18	β Lyrae	20	17	24	0
V Centauri	6	17	8	4	S Crucis	20	20	22	8
S Crucis	6	17	8	5	X Sagittarii	20	22	23	19
X Sagittarii	6	21	9	18	W Sagittarii	21	4	24	4
U Aquilae	7	7	9	11	T Vulpeculae	21	5	26	14
Y Ophiuchi	7	13	13	18	Y Sagittarii	21	6	23	1
T Velorum	7	18	9	3	U Aquilae	21	8	23	12
β Lyrae	7	19	11	2	TX Cygni	21	9	26	12
T Vulpeculae	7	21	9	6	T Velorum	21	17	23	2
S Sagittae	7	23	11	9	R Crucis	22	5	23	14
SU Cygni	8	5	9	13	S Muscae	22	17	26	4
W Geminorum	8	8	10	23	S Triang. Austr.	22	22	25	0
δ Cephei	8	10	9	19	RV Scorpii	23	0	24	10
S Normae	9	12	13	22	T Crucis	23	1	25	2
T Crucis	9	14	11	15	V Centauri	23	4	24	15
Y Sagittarii	9	17	11	12	κ Pavonis	23	5	27	0
T Monocerotis	9	22	17	20	V Velorum	23	14	24	13
S Triang Austr.	10	7	12	9	SU Cygni	23	15	24	23
V Velorum	10	11	11	10	W Geminorum	23	19	26	10
R Crucis	10	13	11	22	δ Cephei	24	12	25	21
RV Scorpii	10	21	12	7	Y Ophiuchi	24	15	30	20
U Vulpeculae	10	22	13	1	S Sagittae	24	17	28	3
S Crucis	11	10	12	22	ζ Geminorum	24	18	29	18
SU Cygni	12	2	13	10	V Carinae	25	11	27	15
V Carinae	12	2	14	6	S Crucis	25	12	27	0
V Centauri	12	5	13	16	T Vulpeculae	25	15	27	0
η Aquilae	12	7	14	16	T Velorum	26	8	27	17
T Vulpeculae	12	8	13	17	U Sagittarii	26	13	29	12
T Velorum	12	10	13	19	η Aquilae	26	15	28	23
X Cygni	12	19	19	0	U Vulpeculae	26	21	29	0
S Muscae	13	1	16	12	Y Sagittarii	27	0	28	19
U Sagittarii	13	2	16	1	β Lyrae	27	4	30	6
W Sagittarii	13	14	16	14	SU Cygni	27	11	28	19
δ Cephei	13	19	15	4	X Sagittarii	27	22	30	19
X Sagittarii	13	21	16	18	R Crucis	28	1	29	10

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum. d h	Maximum. d h		Minimum. d h	Maximum. d h
U Aquilae	Aug. 28 8	Aug. 30 12	T Crucis	Aug. 29 18	Aug. 31 19
V Centauri	28 16	30 3	δ Cephei	29 21	31 6
W Sagittarii	28 19	31 19	T Vulpeculae	30 2	31 11
V Velorum	28 23	29 22	S Crucis	30 5	31 17
S Normae	29 0	33 10	T Velorum	30 23	32 8
RV Scorpii	29 1	30 11	W Virginis	31 5	39 10
X Cygni	29 4	35 9	SU Cygni	31 7	32 15
S Triang. Austr.	29 6	31 8			

Approximate Magnitudes of Variable Stars May 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn
T Androm.	0 17.2	+ 26 26	*s*	R Camel.	14 25.1	+ 84 17	9.5*i*
T Cassiop.	0 17.8	+ 55 14	10.0*d*	R Bootis	14 32.8	+ 27 10	7.5*d*
R Androm.	0 18.8	+ 38 1	8*d*	S Librae	15 15.6	− 20 2	8.5*i*
S Ceti	0 19.0	− 9 53	*s*	S Serpentis	15 17.0	+ 14 40	12*i*
S Cassiop.	1 12.3	+ 72 5	14*f*	S Coronae	15 17.3	+ 31 44	8.5*d*
R Piscium	1 25.5	+ 2 22	*s*	S Urs. Min.	15 33.4	+ 78 58	11*d*
R Trianguli	1 31.0	+ 33 50	12*d*	R Coronae	15 44.4	+ 28 28	6
U Persei	1 52.9	+ 54 20	12*d*	V "	15 45.9	+ 39 52	8.5
R Arietis	2 10.4	+ 24 36	*s*	R Serpentis	15 46.1	+ 15 26	11*i*
o Ceti	2 14.3	− 3 26	*s*	R Herculis	16 1.7	+ 18 38	13*d*
S Persei	2 15.7	+ 58 8	11	R Scorpii	16 11.7	− 22 42	13*d*
R Ceti	2 20.9	− 0 38	*s*	S "	16 11.7	− 22 39	11*i*
U "	2 28.9	− 13 35	*s*	U Herculis	16 21.4	+ 19 7	9*d*
R Persei	3 23.7	+ 35 20	9	W Herculis	16 31.7	+ 37 32	12.5*d*
R Tauri	4 22.8	+ 9 56	*s*	R Draconis	16 32.4	+ 66 58	11.3*d*
S "	4 23.7	+ 9 44	*s*	S Herculis	16 47.4	+ 15 7	12*f*
R Aurigæ	5 9.2	+ 53 28	8.7*d*	R Ophiuchi	17 2.0	− 15 58	*f*
U Orionis	5 49.9	+ 20 10	6.4	T Herculis	18 5.3	+ 31 0	7.5*i*
R Lyncis	6 53.0	+ 55 28	14*f*	R Scuti	18 42.2	− 5 49	5*i*
R Gemin.	7 1.3	+ 22 52	13.7*d*	R Aquilae	19 1.6	+ 8 5	7*i*
S Canis Min.	7 27.3	+ 8 32	9.8*d*	R Sagittarii	19 10.8	− 19 29	*f*
R Cancri	8 11.0	+ 12 2	11*d*	S "	19 13.6	− 19 12	*f*
V "	8 16.0	+ 17 36	9.0*d*	R Cygni	19 34.1	+ 49 58	13*d*
S Hydrae	8 48.4	+ 3 27	12.0*d*	RT "	19 40.8	+ 48 32	8*i*
T "	8 50.8	− 8 46	10.4*d*	X "	19 46.7	+ 32 40	12*d*
R Leo. Min.	9 39.6	+ 34 58	12.5*d*	S Cygni	20 3.4	+ 57 42	*f*
R Leonis	9 42.2	+ 11 54	7.0*i*	RS "	20 9.8	+ 38 28	9.3
R Urs. Maj.	10 37.6	+ 69 18	11*i*	R Delphini	20 10.1	+ 8 47	*f*
R Comae	11 59.1	+ 19 20	*f*	U Cygni	20 16.5	+ 47 35	8
T Virginis	12 9.5	− 5 29	12.3*d*	V "	20 38.1	+ 47 47	11*d*
R Corvi	12 14.4	− 18 42	11.5*d*	T Aquarii	20 44.7	− 5 31	*f*
Y Virginis	12 28.7	− 3 52	*f*	R Vulpec.	20 59.9	+ 23 26	8
T Urs. Maj.	12 31.8	+ 60 2	9*i*	T Cephei	21 8.2	+ 68 5	7*d*
R Virginis	12 33.4	+ 7 32	10.7	S "	21 36.5	+ 78 10	8
S Urs. Maj.	12 39.6	+ 61 38	8.3*i*	S Lacertae	22 24.6	+ 39 48	*s*
U Virginis	12 46.0	+ 6 6	9.0*i*	R "	22 38.8	+ 41 51	*s*
V "	13 22.6	− 2 39	*f*	S Aquarii	22 51.8	− 20 53	*s*
R Hydrae	13 24.2	− 22 46	5.7*d*	R Pegasi	23 1.6	+ 10 0	*s*
S Virginis	13 27.8	− 6 41	12	S "	23 15.5	+ 8 22	*s*
R Can. Ven.	13 44.6	+ 40 2	9	R Aquarii	23 38.6	− 15 50	*s*
S Bootis	14 19.5	+ 54 16	13*d*	R Cassiop.	23 53.3	+ 50 50	9*d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

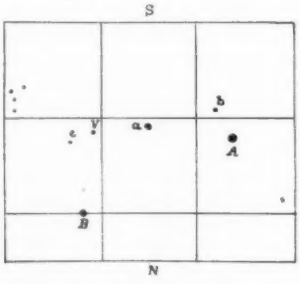
Derived from observations made at the Halsted, McCormick, Vassar College and Harvard Observatories.

The Suspected Variable 9.1904 Orionis.—This star, which was noted in the May number of POPULAR ASTRONOMY, was observed here as a comparison star of 2100 U Orionis on fourteen dates from 1903 September 18, to 1904 March 4, with Pickering's equalizing wedge photometer attached to the 58.4 cm. refractor. Two observations were made by Professor W. M. Reed; the rest were made by the writer. At each observation the star was compared with Hagen 21 (BD. + 20°1179). The observed difference between the two stars ranged from $0^m.28$ to $1^m.02$, indicating a variation of $0^m.74$. These observations do not agree with the period given by Luther. A number of other periods were tried, but none was found that would fit the observations.

PRINCETON UNIVERSITY, ZACCHEUS DANIEL.
PRINCETON, N. J., 1904 May 18.

New Variable 15.1904 Geminorum.—This is announced by Mr. K. Bohlin, of Stockholm, in A. N. 3944. It is a 12th magnitude star near the 5th magnitude star east of δ Geminorum. The accompanying chart shows the stars in its vicinity. Mr. Bohlin gives the following list of comparison stars:

	No.	Mag.	R. A. 1900.0	Decl. 1900.0
			h m s	° ′
A	2953	5.5	7 21 48	+ 21 39.1
b		10		
a	2948	9.1	7 21 19	+ 21 37.7
B	2945	6.4	7 20 56	+ 21 44.2
c		13		



VICINITY OF THE VARIABLE STAR
15.1904 GEMINORUM

The time of variation at minimum is apparently less than 28 days, while the total period may be 338 days, or possibly 169 days, but probably not less than 169 days. The next minimum is predicted for Dec. 24, 1904.

New Variable 16.1904 Persei.—This is in the great cluster χ Persei and was found by Mme. L. Ceraski on the photographic plates taken by M. S. Blajko at Moscow. It is No. 111 on Vogel's chart and No. 120 on Pihl's chart of the cluster. The BD. gives this star as 8.6^m, Vogel, 8.5-8.6, Pihl, 8.5 and Berlin A. G. C. 8.5. On April 1 and 2, 1904 Mr. Blajko saw it as 10.0^m. The position of the star for 1900.0 is

R. A. $2^h\ 15^m\ 20^s.36$; Decl. + 56° 39′ 06″.1

The period and character of its light changes is unknown.

New Variable 17.1904 Andromedæ.—In A. N. 3944 Mr. A. Stanley Williams calls attention to this star and gives its period as 182 days and the range of variation as nearly two magnitudes (8½-10½). The star is BD. + 48°616 and its position for 1855 is

R. A. $2^h\ 01^m\ 41^s$; Decl. + 48° 14′.7

Future minima should occur on July 29, 1904, and Jan. 27, 1905, and a maximum probably about Oct. 28 next.

New Variable Star 18.1904 Ophiuchi.—A new variable BD. + 9°.3414 has been found by Mme. L. Ceraski on the photographs taken at Moscow. The position for 1900 is

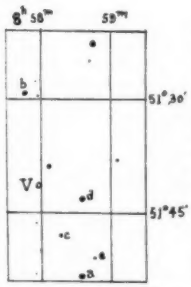
R. A. $17^h\ 28^m\ 27^s.6$; Decl. + 9° 29′.9.

The variation appears to be between 9.0 and 12, but the period is unknown.

New Variable Star 19.1904 Leonis Minoris.—Mr. T. D. Anderson announces, in A. N. 3946, a star which is not included in the BD. whose approximate place for 1855.0 is

R. A. $9^h\ 45^m\ 4^s$; Decl. + 35° 36′.5.

It is at present slowly but steadily decreasing, having changed from 8.4 Mar. 10 to 8.9 Apr. 30. These estimates have been made on the assumption that the neighboring stars BD. + 35°2077 and 2078 are 8.3^m and 9.1^m respectively.



VICINITY OF V URS. MAJ.

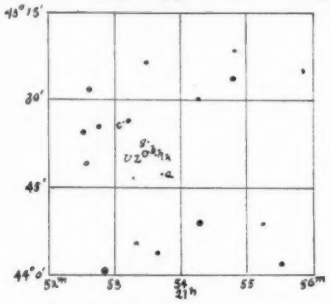
The Light Changes of the Variable V Ursæ Maj.—In A. N. 3941 Dr. K. Graff, of Hamburg, gives the results of a series of observations of this star extending from March 24, 1902 to Oct. 7, 1903. He finds the period to be 201.5 days, the star remaining constant at $9^m.6$ for 98 days, then falling slowly to a minimum at $10^m.6$ and slowly rising again. It thus appears to be an Algol type variable of exceptionally long period. The following provisional elements are given:

Minimum = 1903 April 26 (J.D. 2416231) + $201^d.5$ E.

The accompanying chart shows the stars in the vicinity of the variable. The positions of the brighter stars are:

	R. A. h	m	s	Decl. °	′	Mag.		°
—	8	58	45	+ 51	22.6	8.0	DM.	+ 51.1485
a	8	58	35	51	53.4	9.20	DM.	51.1484
b	8	57	45	51	29.0	9.75	DM.	+ 51.1483
c	8	58	16	51	48.0	10.50		
d	8	58	36	51	43.2	9.90		
e	8	58	46	+ 51	51.0	10.40		

UZ Cygni.—Dr. Hartwig in A. N. 3944 announces an observation of a secondary minimum of this star, midway between the ordinary minima. This star has been regarded as of the Algol type with the long period of 31.4 days.



VICINITY OF UZ CYGNI.

The principal minimum occupies about 60 hours, while the secondary lasts only about 8 hours. The accompanying chart gives the relative positions of the variable and the neighboring stars.

GENERAL NOTES.

Mountain Station for Goodsell Observers.—As will be noticed elsewhere in this issue, a preliminary statement regarding astronomical work for the months of July and August has been made. Some years ago we visited the Rocky mountains in the summer for the purpose of learning something of the advantages of elevations there for observing purposes. It was then learned that some localities visited gave promise, in a preliminary way, of that which was wanted for certain kinds of astronomical work that need to be done.

These places were situated near the Great Northern Railway in the Rocky mountains in the vicinity of the summit of the range. The general altitude below the more abrupt columnar elevations or peaks of the range is about 5,000 feet above the level of the sea. Wide areas with elevation but a little less are found in this neighborhood within a circuit of ten or fifteen miles. If other conditions needed are found thereabout, favorable summer observations may be made in the line desired. It is the present intention of the Director of Goodsell Observatory to make further trial, to know if this altitude, which is easily accessible, is really good enough in other respects for the kind of work which we are planning for, and hoping to do somewhere.

We have been greatly encouraged by thoughtful, able and interested friends who have provided the expenses for this expedition without certain knowledge on the part of any one that it will be a success.

Columbia University Observatory.—Dr. Harold Jacoby has been promoted to a professorship in astronomy at Columbia University. Professor J. K. Rees, the Director of the Observatory, has his leave of absence continued until July 1905. Professor Jacoby will remain acting Director during Professor Rees' absence. Dr. Charles L. Poor of Johns Hopkins University has been appointed Professor of Astronomy and he will be associated with Professor Jacoby.

The Swasey Depression Range Finder.—Messrs. Warner and Swasey of Cleveland, Ohio, have recently been interested in bringing out an instrument called The Swasey Depression Range Finder. Its purpose is indicated in its name. To make it as complete and as efficient as possible, allowance must be made for variable refraction, height of tide at the position of the object, the range of which is being found and the curvature of the Earth.

The accuracy that the makers have reached is an error which comes within one-half of one per cent, on the longest range, and in many instances, the error does not exceed one quarter of one per cent. The important thing about this new instrument is the small error in range that is last noted above. On this account the Government has become interested in this useful instrument and has already purchased for its own use a hundred or more of them. The tests already made by government officers prove very satisfactory.

We have seen a detailed description of the instrument, and it is of such general interest that we will soon publish it with illustrations to aid the general reader in understanding what it is for and how it works.

The Fifth Satellite of Jupiter.—Number 51 of the Lick Observatory Bulletin consists chiefly of the observations of the fifth satellite of Jupiter in 1903 by R. G. Aitken. One feature of these observations is especially noteworthy. He says: "From the observing notes given with each night's measures it will be noticed that the Fifth satellite was very easily seen this year. It was so bright that on one or two nights I was in doubt for a time as to whether the object seen might not be a small star, and I am satisfied that a 14th magnitude star within 25″ of the planet's limb would appear fainter than the satellite did."

New Glass for Lenses.—The fine qualities of glass made at Jena have revolutionized the construction of lenses, especially for strong visual or photographic work. It is claimed by those who are expert in such things that combinations of certain kinds of glass can now be made which have been heretofore regarded as impossible, and that from these new combinations some properties are secured that are full of promise. Those but little acquainted with the art of glass-making will easily remember that it is only a few years ago that the really scientific method for the production of specific kinds of glass was brought to such a degree of perfection at Jena, that the lenses for microscopes were so greatly improved that work with that important instrument was given a fresh impulse everywhere. The great reputation of the Jena manufacturers was made almost in a day.

Astronomers then began to look into the matter. At first they were a little skeptical, although the specimens examined were almost perfectly clear, colorless and remarkably light of weight. The source of uncertainty for the astronomer lay in the direction of the hygrometric qualities of some of the early specimens. The fear was that the glass would not be durable. Its qualities would deteriorate. If this should prove true, it would never do for large astronomical lenses. At first, on this account, only small lenses for telescopes were made for trial. As far as we know, the fear of the astronomer has not been realized. Large glasses are now made of the Jena product and it stands the severest test, both of varying temperature and of moisture and deteriorating for a period of eighteen years, at least. The important change that has come from the new process of glass-

making is the fact that a purchaser can now leave an order for a specific kind of glass whose properties are specified to the last detail, and the manufacturer takes that order into his laboratory and makes the glass according to the order, as a druggist would fill the prescription of a physician.

The optician will then make a prism from a piece of the glass so manufactured, and examine its work by the aid of the spectroscope to see if the glass chemist has done his work well, and also to see if the constants obtained are such as the mathematician wants for his curves for the telescope objective that he has promised to construct for some physicist anxious to do critical work of some kind in his investigations.

From such a chain of circumstances as this it does not require very great insight or scientific knowledge to show how important the improvement in the quality of glass may be in carrying forward any one of a dozen different lines of physical research.

Notice of an interesting paper pertaining to this matter has just come to hand in the British Journal of Photography, which was read recently before the Royal Society of London, from which we take the following extract:

"The authors of the paper have made a number of measurements of the optical constants of the new material, which possesses great uniformity of composition, combined with transparency to ultra-violet radiations, while, unlike quartz, it is not doubly refracting. To test the homogeneity and, consequently, perfection of refracting power of the new medium, four slabs of it were prepared, cemented together, and from the mass a prism cut and polished. Any variation of density on any one of the slabs would have so affected the refraction as to render the prism useless as an instrument of precision; but so far was this from being the case that when tested against a similar prism of boro-silicate glass from Jena, all the slabs being from the same melting, the silica prism was found to be distinctly superior. A thin doublet had been made and was described; it had the vitreous silica for one component and fluorite for the other; the focal length of the combination is almost independent of the wave-length, in other words, the achromatism was almost perfect."

Brilliant Meteor.—An exceedingly brilliant meteor was seen from this place last Saturday evening, May 14, at $9^h\ 55^m$ central standard time. It fell from the direction δ Herculis towards the Earth on a straight line inclined 20° from the perpendicular towards the north. It was twenty minutes of arc in diameter, and allowing for irradiation probably it must have been at least fifteen minutes. It was of dazzling white, nearly round, very nearly pear shaped, but it left no train. It lasted a second and a half and disappeared two degrees above the horizon. I could not estimate its distance, but thought it to be 50 or 60 miles away, possibly much more. It appeared first at a height of 23°. It illuminated the atmosphere and eastern horizon very brightly while it lasted.

CHATTANOOGA, Tenn., H. L. SMITH.
May 16, 1904.

Precession and Assyriological Discoveries.—Mr. Maunder at the April meeting of the Royal Astronomical Society made some interesting statements about precession as it appears in books and articles dealing with Assyriological discoveries. He said the paper which he had to submit to the Meeting was in rather strong contrast to those which they had been considering, for in-

stead of dealing with the most recent advances in theory and observation, it went back to the astronomy of 4000 or 5000 years ago. Mrs. Maunder and he had been led to write the paper from noticing the very loose way in which the effect of precession was referred to in books and articles dealing with Assyriological discoveries. Thus 2500 B. C. was often given as the date when the Sun at the spring equinox ceased to be in Taurus, and was recognized as in Aries. It had even been stated that the Sun was at the First Point of Aries at the spring equinox in 2540 B. C., whereas it had that position only about 150 B. C. Of course these dates assumed that the ancient Accadians and Assyrians considered the Sun as amongst the stars with which it was in conjunction. But it was possible that they associated the Sun with the stars with which it was in opposition, or by means either of the heliacal risings or settings of the stars. None of these four methods appears to have been the primitive one. But a fifth was in use at a very early age. It consisted in watching the position of the new Moon when first seen at the beginning of the year relative to a certain bright star. This star seems to have been Capella. It followed that the beginning of the second month was similarly marked by the seleniacal setting of Castor and Pollux. So long as this method was in use Taurus must have been the constellation associated with the first month of the year, and Gemini with the second. In accordance with this relation the signs for the patron deities of the first two months were a crescent moon "on its back" for the first month, and a pair of stars, for Istar and Tammuz, the "Heavenly Twins," for the second. The crescent Moon is of course more completely "on its back" when setting at the spring equinox than at any other time of the year. (Mr. Maunder showed some slides of boundary stones, dedicatory tablets, and signets, showing the three symbols alluded to).

Mr. Maunder continued that the second period of ancient astronomy, when Aries was taken as the first sign of the zodiac, probably arose during the period of great intellectual activity in Assyria associated with the reign of Assur-banipal. Hamal, the chief star of Aries, was in conjunction with the Sun at the spring equinox B. C. 700, and the equinox was observed directly by means of some mechanical method for determining time. The planets were observed in this age, and the various statements made about the god Marduk as the planet Jupiter showed that the value of that planet had been recognized as a means of determining the point of the sky in opposition to the Sun, and that the motion of that planet through a twelfth part of the ecliptic in the course of a year, and its division of that arc into three equal parts by its retrogression through 10 degrees, had also been noted.—*The Observatory*, April, 1904.

Lack of Transparency of Earth's Atmosphere.—The following circular letter was not received until May 3. This is the reason why notice of it appears late:

"You may have noticed that records have been published by Messrs. C. Dufour of Lausanne; H. H. Kimball, S. P. Langley, and C. G. Abbot of Washington; Max Wolf of Heidelberg; and Gorczynski of Warsaw; showing that an appreciable general diminution of the transparency of the Earth's atmosphere took place some time during the year 1902, but disappeared at some time during 1903. This is an important matter and may possibly be made the basis of an explanation of other meteorological phenomena. I beg to ask whether you have any records that will assist in defining the dates of beginning and ending, and

the extent of this change in transparency. Such records may consist of photometric or photographic observations of the brightness of the stars; changes in the solar or stellar spectra; unusual prevalence of halos, large Bishop's ring, or haze; observations of heat received from the Sun, as made with actinometers or pyrheliometers; observations of the polarization of the blue sky light and of scintillation of the stars.

"Undoubtedly this diminution and increase of transparency began and ended at different dates in different places, as the phenomena spread gradually over the world during the years 1902 and 1903; additional records are therefore desired in order to trace its progress. Will you not kindly examine your records from this point of view and send me the result for publication in a general article on this subject? CLEVELAND ABBE. Professor and Editor."

U. S. DEPT. OF AGRICULTURE, WEATHER BUREAU, April 15, 1904.
WASHINGTON, D. C.

New Determination of the Axis of Rotation of Mars by Percival Lowell.—In Bulletin No. 9 from Lowell Observatoty is found a full paper by Percival Lowell on a new determination of the position of the axis of rotation of the planet Mars. We give the results of this interesting piece of astronomical work.

At the conclusion of this paper Mr. Lowell says:

"Deductions of the position of the true pole of the planet from various such combinations follow. First comes that from the observations of 1901 and of 1903 complete; next that from those of 1901 and 1903 expurgated; third, that from the measures of 1903 before and after opposition, complete; and fourth, that from the same expurgated. After which follow results from Schiaparelli's measures of 1882, 1884 and 1886, combined in pairs.

	Martian Pole.		Intersection of Martian Equator and Ecliptic.		Tilt of Martian Equator to Martian Ecliptic.
LOWELL— Epoch 1903.	R. A. ° ′	Decl. ° ′	R. A. ° ′	Decl. ° ′	° ′
1901 and 1903—*Unexpurgated*	314 56.2	55 16.2	86 7.3	24 32.1	22 23.0
1901 and 1903—*Expurgated*...	315 7.0	55 2.3	85 50.9	24 31.3	22 37.0
1903—Before and after opposition—*Unexpurgated*	316 47.1	54 31.1	86 39.8	24 33.6	23 40.2
1903—Before and after opposition—*Expurgated*.....	315 56.8	54 39.4	86 0.4	24 31.8	23 13.5
SCHIAPARELLI— Epoch 1903.					
III 1882 and IV 1884.....	319 56.5	54 35.6	90 13.0	24 39.2	24 56.0
III 1882 and V 1886.....	321 0.2	55 11.2	92 25.9	24 41.8	24 58.0
IV 1884 and V 1886.....	320 26.7	55 52.8	93 13.0	24 42.5	24 16.0
STRUVE— Results—Epoch 1903.....	317 16.2	54 38.4	83 43.7	24 24.2	25 12.8

It will be seen how little relative effect the correction for possible error in tilting the eyes occasioned, less than that between the two oppositions considered together and apart; but that it did result in bringing the two results nearer together. It will also be noticed that Schiaparelli's determinations show about the same divergence *inter se* as those of 1901 and 1903. Struve's result differs from both.

From these observations of 1901 and 1903 I conclude, therefore, that the position of the pole of Mars lies midway between the expurgated comparison of 1901 with 1903, and of 1903 before and after opposition, or about as follows:

	R. A.		Decl.	
	°	′	°	′
Position upon the Earth's Equator	315	32	54	51
Intersection of Martian Equator and Martian Ecliptic.	85	56	24	32
Inclination of Martian Equator to Ecliptic			22	55"

Watson's Twenty-two Asteroids.—At the death of Professor James C. Watson, which occurred in 1880, he left a sum of money, as an endowment fund, the income from which should be used to pay for the necessary computations to keep track of his asteroid famiy that none of them should be lost to the scientific world. It is now twenty-four years since this fund was provided and put into the hands of three trustees, who were Professor Simon Newcomb, chairman, Professor Lewis Boss and Professor W. L. Elkin. The plan adopted by the trustees, so far as we know, has been to make tables for these individual asteroids by which their places might be found for fifty years in advance. Up to three years ago when the work was undertaken by the Astronomical Department of the University of California, considerable had been done, but little was ready for publication. There are probably some good reasons why this work has been delayed so long. As a consequence, apparently, Aethra, one of the twenty-two is lost. Its path passes very near to that of Mars, and of course that asteroid would suffer in consequence violent perturbations, and its orbit has been probably greatly changed, for diligent search for it has not been successful up to the present time. In consequence of this lapse special investigation will be necessary to recover the lost child of this family. From a recent number of the Publications of the Astronomical Society of the Pacific (No. 95) it is learned that Miss Hobe will undertake this work. From the same source it is also learned that the entire direction of looking after and caring for this group of asteroids has been turned over to Professor Leuschner of the University of California.

During the last three years the perturbations of ten asteroids have been computed at Berkeley, those of two more are nearing completion and five others are under way. "The four remaining ones have been investigated by other astronomers in Europe ard America." Evidently this important piece of work is in good hands and it will be pushed to completion in less than twenty years.

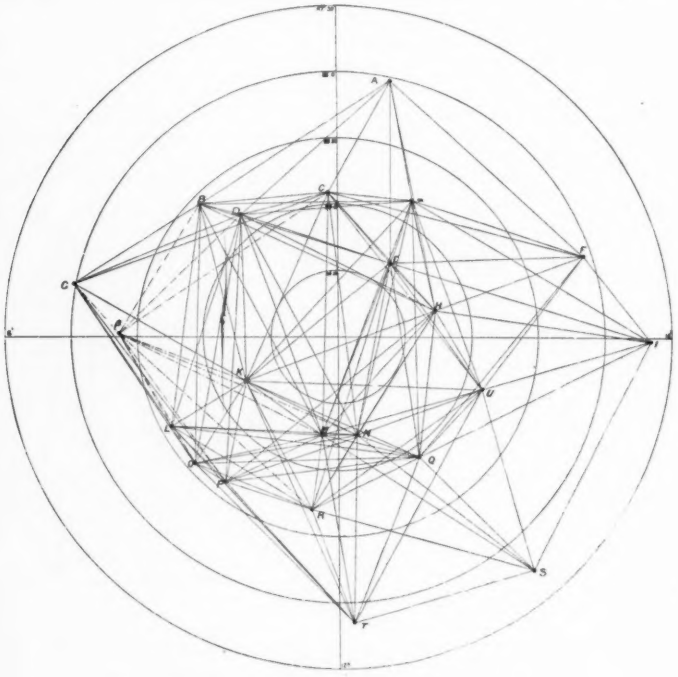
Heliometer Triangulation of the Circumpolar Region.—We have received part one of the Annals of the Cape Observatory, Vol. XI, on Southern polar researches, the principal part of which pertains to the heliometer triangulation of the southern circumpolar area. This work was done by S. S. Hough, chief assistant of the Royal Observatory, under the direction of Sir David Gill.

This paper is intended as the first of a series of memoirs to be devoted to the discussion of all accurate data pertaining to the positions of the stars surrounding the South Pole of the Heavens. The Poles of the celestial sphere are fundamental points in sidereal astronomy, and accurate knowledge of their positions is of course, of the greatest importance. Determinations of these points have been made usually from a knowledge of the positions of circumpolar stars. But the places of such stars have not been determined generally with sufficient ac-

curacy to give the position of the Pole, as exactly as it ought to be known for the real needs of modern astronomical work usually made to depend upon the assumed or predetermined place of this reference point. It is also true that there is no bright star near the South Pole which can be observed in daylight, so that work must be largely confined to the winter months on such circumpolars as are available near sunset and sunrise times.

Under such circumstances the heliometer triangulation of stars extending to rather more than 2° from the Pole has been carried forward to completion. It is planned that further memoirs will be made, and that they will deal with (1), the discussion of a series of photographic plates covering the circumpolar area; (2), a series of fundamental determinations made with the new Cape Meridian Circle; (3), the final adjustment and combination of all existing material suitable for the purpose.

The accompanying figure shows how the triangulation was planned and the extent to which it was carried out. The writer of the paper speaks of the precision of the results obtained as considerable although somewhat disappointing,



TRIANGULATION OF SOUTHERN CIRCUMPOLAR STARS.

as compared with others previously secured by the aid of the Cape Heliometer. He accounts for this from two circumstances. One is "the comparatively low altitude at which the observations were necessarily made, and the other the fact, that in the early stages the observers were largely inexperienced at refined astro-

nomical work of this character, and at the later stages, the instrument itself had developed defects due to wear, which may have materially influenced the precision attainable with it."

The work of chapter twelve which was done after the instrument had been thoroughly overhauled was independently reduced, and it shows improvement in the results in both directions.

Determination of the Relative Masses of 70 Ophiuchi.—In A. N. 3946 Mr. Adalbert Prey of Vienna gives the results of an investigation of the ratio of masses of the components of the binary star 70 Ophiuchi, using 33 meridian observations of the principal component. He obtains the remarkable result that the center of gravity of the system is four-fifths of the way from the principal component to the companion, so that the mass of the companion must be four times as great as that of the brighter star. Using Schur's parallax 0".16, he finds the masses of the two stars to be 0.32 and 1.28 times the Sun's mass. Mr. Prey wishes to carry this investigation further and requests all observers who have unpublished observations of this star to communicate them to him.

The Telescope.—In D. Van Nostrand Company's Scientific Series, No. 51 has for its title, The Telescope, and the first edition of that book was prepared in 1879 by Thomas Nolan. The conditions under which that very useful little book was published were unknown to us until very recently. They are worth repeating, because they show the origin of the book and the opinion of some able astronomers concerning its real worth. The first edition was an 18 mo. volume in boards of 75 pages, which was the first half of a dissertation, written in part fulfillment of the requirements in competing for the John F. Stoddard one-hundred-dollar gold medal awarded by the University of Rochester, N. Y. At the suggestion of one of the examining committee, Professor William A. Rogers, at that time at Harvard University, the dissertation was published, first in Van Nostrand's Magazine, and afterwards reprinted in book form which sold at 50 cents.

During the year 1904, a second edition of this book has been published by the Van Nostrand Company, of New York, in revised and enlarged form. An entirely new chapter on the evolution of the modern telescope and a bibliography up to date has been added. It is of the same form as the first edition, containing 118 pages and sells at 50 cents.

Any one desiring knowledge of the optical principles involved in the construction of refracting and reflecting telescopes, will find this little handy volume worth many times its cost to them.

λ Andromedæ.—In *The Observatory* for May 1904 Mr. J. E. Gore calls the attention of astronomers engaged in the determination of stellar parallax to the case of the spectroscopic binary λ Andromedæ, discovered as a binary by Campbell in 1899. The period is about 19.2 days and the orbital velocity 5.6 miles a second, the companion being a dark body. From various considerations Mr. Gore estimates the mass of the system to be not more than 1/10 the mass of the Sun, and therefore, since the star is of the fourth magnitude, that it must

be comparatively near the Sun. He estimates that the parallax may be as large as 0″.34, so that an effort should be made to measure it. The star has a proper motion, according to the Greenwich 10-year Catalogue, of 0ˢ.0157 in R. A. and 0″.425 in declination.

Radial Velocities of Twenty Stars by Frost and Adams.—This paper is another of the so-called decennial publications of Chicago University that have recently appeared, and some of which have received full notice in this journal in recent months past. The full title of the paper is, "Radial Velocities of Twenty Stars having Spectra of the Orion Type." The paper was prepared by Edwin B. Frost and Walter S. Adams of Yerkes Observatory, Williams Bay, Wisconsin. It begins with a brief reference to the history of the determination of the velocity of a star in the line of sight according to the Doppler-Fizeau principle, first attempted by Huggins in 1868, and by Vogel a little later, both of whom established the principle, as a method of investigation which has since been applied by many others to the study of the motions of nearly all celestial bodies.

The next step in advance noticed, was due to Campbell of Lick Observatory, who has done important work with the Mills spectrograph, an instrument of his own design, and the three things mentioned which give his work preëminence are, the use of iron as a comparison spectrum, the close attention to the optical and mechanical construction of the spectrograph and the refinement in the measurement of his photographic plates. On account of this three fold advantage the unit of measure has been changed from the German mile used by Vogel to the kilometer, a value only about one-seventh as great as that formerly employed.

The next point of interest in improving the spectrograph was to make it rigid to prevent flexure, and to maintain a constant temperature for the prisms while in use. From this paper it would appear that special attention was given to these things in the construction of the Bruce spectrograph of the Yerkes Observatory which was completed in the autumn of 1901, and which has been used in the observations that are the basis of this paper.

The work done is the most important part of all, and the choice of stars of the Orion type is of special interest because some physicists think that this class of stars occupy a position very early in the scale of stellar evolution. This is evidently the view of the authors of this paper. We think it is too much to say that there is general agreement of astronomers on this point. "The chemical constitution of these stars is simple, the chief elements showing lines of hydrogen, helium, oxygen, silicon, nitrogen and magnesium. The presence of helium is the principal characteristic of the type, whence they are frequently called helium stars."

The first point of difficulty met in the study of the radial velocity of these stars is the broad and diffuse nature of most of the lines of these spectra. Exact measurement is very difficult. Then, if the spectroscopist has an instrument of high dispersion like that of the Bruce spectrograph the difficulty of precision in measurement is increased. On this point the authors have given tests of the accuracy of their work that leaves no doubt in the mind of the critical reader of this paper, regarding the degree of accuracy reached in observation, measurement and reduction. They also speak of the optical features of the Bruce spectrograph, indicating that they were especially planned to cover a region of the spec-

trum, not naturally included by most of the large spectrographs engaged in radial work, and therefore centering it near the strong helium line (λ 4471) and the characteristic line of magnesium (λ 4481), this region being well suited for work on the Orion stars. A further reason for choosing this field of work is the fact that it has been little observed for radial velocity, and it is therefore one needing attention.

The choice of these twenty stars is from a list of something over one hundred stars of the Orion type observed by Vogel and Wilsing, exclusive of spectroscopic binaries previously known to be such. The description of the instruments used in this work is full and definite and apparently complete. Since the spectrograph has been in use a number of minor changes have been made which improve its working efficiency. For a fuller knowledge of details of instruments, methods of work, way of reduction and the combination of results, our readers are referred to the paper which is in octavo form and contains 108 pages of closely printed matter.

Near the end of the paper is an important page (106) which concerns the classification of the spectra which this study has brought out. The points made are, that the stars investigated belong to type I*b* of Vogel's classification, but, in some respects would be better represented by Miss Maury's divisions, because hers shows a very wide range of spectrum including the H and K region; that there is a disadvantage in discussing radial spectra because the plates best adapted to this kind of work are generally quite different from those most suitable for qualitative examination. In what respects the plates are different the authors do not state, unless it is by inference, in regard to density which effect faint lines; that there are advantages in higher dispersion and a consequent broadening of the lines, for these conditions enable one to judge much better of the behavior and character of individual lines than would be possible with low dispersion and a small scale; and that the stars so far observed are too few for more than a mainly empirical classification, "and any order of arrangement will represent the succession of the various spectra as regards complexity and character of the lines rather than the sequence of development of the stars themselves." This last statement is significant, and it is the language of the authors, except for the position of one word that is changed for the sake of clearness in meaning.

As already stated, the lines that have been investigated, and are to be classified on some plan, are those from the elements: hydrogen, helium, magnesium, silicon, oxygen and nitrogen. Only a few lines are yet to be identified, and the extent of the spectrum in this work was from λ 4300 to λ 4720.

From this point the authors speak of the order of the development of certain stars in this group, and the statements made are so definite that we wish our readers to have their own words. They are as follows.

"In what are probably the earliest stars of this type in order of development no lines are present with the exception of the hydrogen and stronger helium lines, and these are faint, and extremely broad and diffuse. Most of them contain the line Hγ' at λ 4542, which belongs to the series of hydrogen lines first found by Pickering in the spectrum of ζ Puppis, and some of them show the line at λ 4686, which Rydberg calls the first line of the hydrogen spectrum. Both of these lines are represented by bright bands in the spectra of stars of the Wolf-Rayet type. In the stars which appear most naturally to come next in order these lines disappear, and the hydrogen and helium lines increase in strength, at the same time becoming narrower and more sharply defined. The earliest of this

group of stars show traces of the magnesium line at λ 4481, and the silicon lines at λ 4553, λ 4568 and λ 4575. While the magnesium line, however, rapidly increases in strength, becoming in the later stars of the group one of the most prominent lines in the spectrum, the silicon lines remain comparatively unimportant. The spectra of the furthest developed stars of this sort, such as ι Herculis and β Orionis, are characterized by strong and fairly well defined lines of hydrogen and helium, a strong and narrow line at λ 4481, and traces of the silicon lines. Faint metallic lines also appear at this point, the most prominent being at λ 4550 and λ 4584, and indicate the connection of these stars with those distinguished by metallic lines. These last are represented among the stars investigated by ζ Tauri, γ Corvi, and η Leonis, and show a great decline in intensity for the helium lines accompanying the rise of the metallic lines. The magnesium line λ 4481, however, is very weak in the case of ζ Tauri, though strong in the other two stars, and this fact, together with the remarkable character of its hydrogen lines, which are of a sharpness and brilliancy not approached in any of the other stars, makes the spectrum of this star one of the most interesting that we have encountered.

"Up to this point the order of succession of the spectra seems to be fairly clear, but those containing oxygen and nitrogen lines are much harder to classify. This difficulty arises from the fact that in other respects they seem to be almost identical with those which we have just considered. There is the same rise in intensity and increase in sharpness on the part of the hydrogen and helium lines, and the magnesium line appears and develops in almost exactly the same way, reaching nearly, though never quite, the intensity which it has in such stars as β Orionis. On the other hand, we find in the earliest stars of this group the beginnings of a whole series of oxygen and nitrogen lines which develop simultaneously with the hydrogen, helium, and magnesium lines, and attain in the later stars of the group, such as β Canis Majoris and γ Pegasi, a high degree of prominence. The fact that the three silicon lines, which in the stars considered before never became at all marked features of the spectrum, now follow the behavior of the oxygen and nitrogen lines and gain in intensity with them, is of interest as showing that the stellar conditions seem to be favorable to the simultaneous development of the spectra of the three elements. An examination of these characteristics of the spectrum appears to make the relationship of this group of stars to that which we have considered before one of parallelism rather than succession. For while the order of succession of the individual stars within the two groups is so well defined as to preclude the insertion of either within the other, an attempt to make one follow or precede the other would be equally difficult, without the assumption of the absence of more connecting links than would be justified. Accordingly, it has seemed best to assume a point of division immediately after the earliest stars of the list, and to arrange the stars exhibiting no oxygen or nitrogen lines in their spectra along one branch, while the stars which are characterized by such lines proceed along the other.

"In the following table the twenty stars discussed in this paper, together with some others of this type of which we have one or more plates, are collected and arranged. Those whose spectra are very closely allied are connected with brackets, and within the brackets the individual stars are placed in the order of increasing intensities of the lines mentioned.

κ Draconis ι Orionis	Only hydrogen and stronger helium lines present with Hγ and λ 4686.
S Monocerotis	All lines extremely broad and diffuse.
λ Orionis	Possibly a trace of λ 4481 in γ Orionis.

π^5 Orionis ε Delphini ε Cassiopeiæ η Lyrae ζ Draconis τ Herculis ι Herculis β Orionis	All lines growing narrower and sharper, with λ4481 and helium lines stronger. Traces of silicon lines. No oxygen or nitrogen lines.	ζ Orionis ε Orionis κ Orionis	Lines stronger than above but very diffuse. Traces of λ 4481 and silicon lines. Traces of a few oxygen and nitrogen lines with strong λ 4649.
ζ Tauri γ Corvi η Leonis	Helium lines much weaker. Metallic lines grow stronger.	67 Ophiuchi 102 Herculis η^4 Orionis χ^2 Orionis γ Orionis ζ Persei η Orionis β Cephei ζ Cassiopeiae ε Canis Majoris β Canis Majoris δ Ceti γ Pegasi	All lines growing narrower and sharper, with λ 4481, helium, and silicon lines stronger. Oxygen and nitrogen lines increase in number and grow sharper and stronger."

On page 105 of this volume of the Decennial Publications is found the final results of the work of Messrs. Frost and Adams, tabulated as is given below:

Mag.	Star.	R. A.	Decl.	Radial Velocity.	No. of Measures.	Epoch.	Proper Motion. R. A.	Proper Motion. Decl.	Great Circle.
		h m	° ′	km.			s	″	″
3.0	γ Pegasi	0 08	+ 14 38	+ **5.4**	12	1902.06	0.0000	— 0.013	0.013
3.7	ζ Cassiop.	0 31	53 21	+ **2.9**	6	1902.10	+ 0.0024	0.007	0.023
3.6	ε Cassiop.	1 47	63 11	— **5.9**	8	1902.08	0.0058	0.017	0.043
3.1	ζ Persei	3 48	+ 31 35	+ **22.1**	7	1901.95	0.0009	0.017	0.020
0.3	β Orionis	5 10	— 8 19	**20.7**	24	1901.95	+ 0.0001	0.001	0.002
1.9	γ Orionis	5 20	+ 6 15	**18.0**	10	1901.98	— 0.0004	0.019	0.020
1.8	ε Orionis	5 31	— 1 16	**26.7**	7	1902.05	0.0000	0.002	0.002
1.9	ζ Orionis	5 36	2 00	**18.3**	7	1902.52	+ 0.0005	0.007	0.010
2.2	κ Orionis	5 43	9 42	**17.1**	10	1901.88	+ 0.0001	— 0.005	0.005
2.0	β C. Maj.	6 18	17 54	**32.6**	5	1901.84	— 0.0004	0.000	0.006
1.5	ε C. Maj.	6 55	— 28 50	**27.2**	4	1902.61	+ 0.0004	— 0.001	0.005
3.6	η Leonis	10 02	+ 17 15	+ **3.5**	5	1902.31	— 0.0001	— 0.012	0.012
2.8	γ Corvi	12 11	— 16 59	— **7.0**	6	1902.27	0.0113	+ 0.011	0.162
3.9	τ Herculis	16 17	+ 46 33	**12.7**	6	1902.21	0.0012	0.031	0.033
3.3	ζ Dracon.	17 08	65 50	**14.4**	8	1902.19	0.0021	+ 0.020	0.024
3.9	ι Herculis	17 37	46 04	**16.4**	6	1901 92	— 0.0010	— 0.006	0.012
4.0	67 Ophiu.	17 56	2 56	**3.1**	4	1902.47	+ 0.0003	0.016	0.017
4.5	102 Herc.	18 04	20 48	**10.8**	5	1902.62	+ 0.0003	0 011	0.012
4.5	η Lyrae	19 10	38 58	**9.1**	6	1902.74	— 0.0002	0.004	0.005
4.1	ε Delphini	20 28	+ 10 58	— **26.2**	4	1902.55	+ 0.0006	— 0.026	0.027

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